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VOLCANIC SUCCESSION AT DECEPTION ISLAND, WEST ANTARCTICA: A REVISED LITHOSTRATIGRAPHIC STANDARD[2]

(Figs 1-26; Tabs 1-3)

Abstract. New lithostratigraphic standard is proposed for the Quaternary volcanic succession at Deception Island, South Shetland Islands (West Antarctica). The succession is subdivided into the older Foster Group (redefined group) which includes pre-caldera volcanics, and the younger Hawkes Group (new group) which includes syn-caldera and post-caldera volcanics and volcanic forms. The Foster Group consists of four formations (new units): the Entrance Fm. (basaltic and basaltic andesite lavas and pyroclastics); the Cathedral Fm. (agglomerates); the Stonethrow Fm. (basaltic andesite lavas alternating with agglomerates); and the Window Fm. (trachybasalt dykes). The Hawkes Group consists of seven formations (new units): the Murature Fm. (andesitic lapilli tuff, destroyed ring tephra cones); the Ronald Fm. (trachydacite lava and plug); the Collins Fm. (trachydacite lava flows, tuffs, craters and destroyed cones); the Chacao Fm. (basaltic andesite tephra cones and maars); the Casco Fm. (basaltic andesite tephra cones with craters); the Kirkwood Fm. (basaltic lavas and tephra; fissure eruptions and craters); and the Telefon Fm. (andesitic tephra cones, lavas and tephra cover associated with fissure eruptions, maars). The Telefon Fm. (three phases) relates to the 1967-1970 volcanic activity; the Kirkwood Fm. includes the 1842 event and the events between 1829 and 1912; all older formations pre-date 1829.

Key words: West Antarctica, active volcano, succession of events, lithostratigraphy

INTRODUCTION

The Deception Island (62°58' S - 60°39' W) is an intermittently active volcano in the South Shetland archipelago, West Antarctica (Figs 1, 2). It forms an open ring 2-5 km wide and about 15 km in outer diameter enclosing an inner elongated lagoon 6 × 10 km in diameter, formed due to caldera collapse. The lagoon communicates with the open sea (Bransfield Strait) through a narrow passage of Neptunes Bellows (Figs 3, 4). It is maximum 190 m deep.

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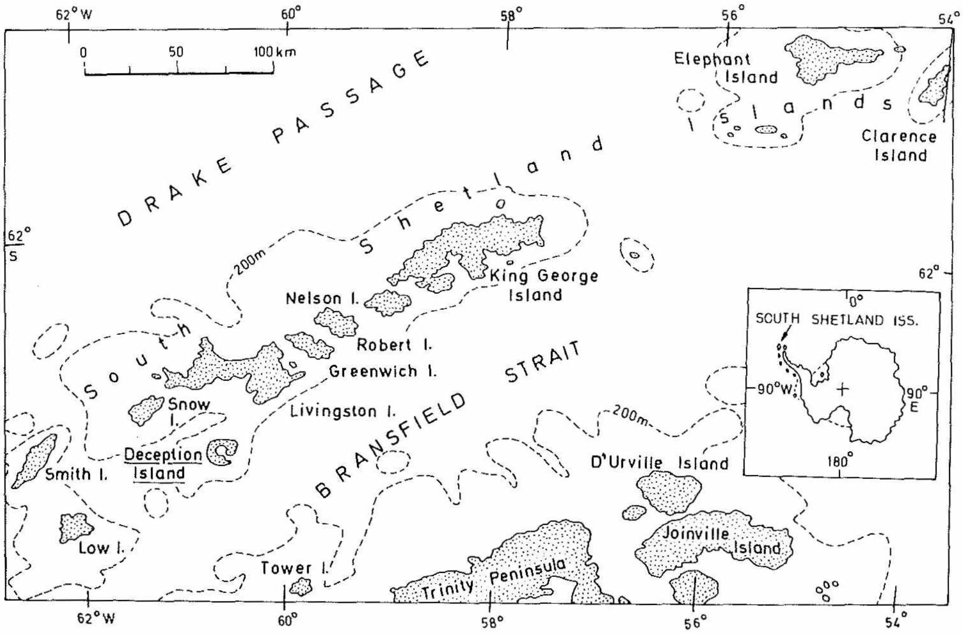

Fig. 1 Location of Deception Island in Antarctica

The submerged basal diameter of the volcano is between 20 and 30 km. The altitudes of the caldera walls attain over 500 m a.s.l. at its eastern rim: Mount Pond (548 m) and Mount Chile (528 m), and over 450 m at its southern rim: Mount Kirkwood (464 m).

The volcano is situated on the north side of Bransfield Strait, just off-axis relative to the marginal basin spreading centre (González-Ferrán, 1991), within the South Shetland crustal block (Ashcroft, 1972; Guterch *et al.*, 1985, 1990; see Fig. 2). It rises about 1200 m above the sea bed (Smellie, 1990).

Since its discovery at the beginning of the 19th century, the island was frequently visited by sealers (mainly between 1820 and 1830), with Sealers Harbour (Cove) used as the main anchorage. Whaling operations between 1910 and 1931 resulted in establishing a Norwegian whaling station with resident British magistrate at Whalers Bay. A British scientific station was built at Whalers Bay in 1944 (destroyed by the 1969 eruption), followed by Chilean Base Pedro Aguirre Cerda at Pendulum Cove (destroyed by the 1969 eruption) and Argentinian Base at Fumarole Bay (at Lago Irízar) during the next decade. Presently, the Argentinian Station, and the Spanish Seismological Observatory (at Punta Casco) established in 1987/8, are the only scientific stations operating on the island during the Antarctic summer.

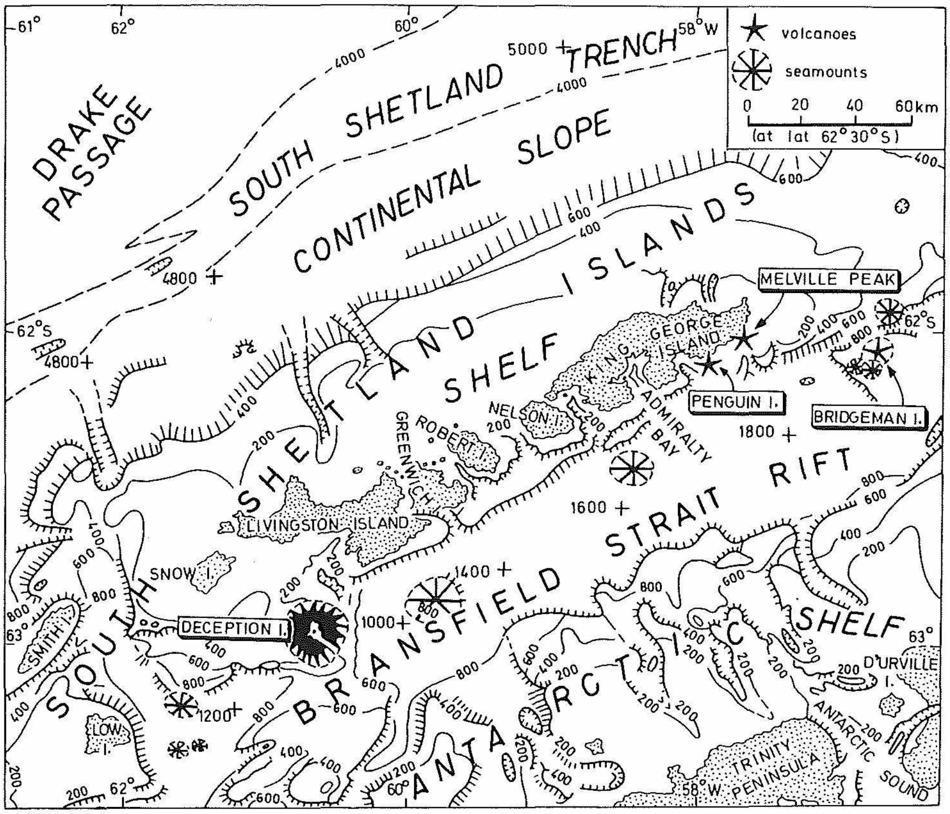

Fig. 2 Location of Deception Island in Bransfield Strait (sumbarine topography modified from Ashcroft, 1972)

ACKNOWLEDGEMENTS

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EARLY INVESTIGATIONS

Although volcanic character of the island was obvious to most of the early visitors, no systematic volcanological studies were carried out until the third decade of the present century (Holtedahl, 1929). Of the early reports should, however, be mentioned: lieutenant R. N. Kendall's description of volcanic activity at Deception Island in 1829, and captain W. H. Smiley's sighting of the 1842 eruption in the southern part of the island (Barrow, 1831; Adie, 1964; Roobol, 1973). Andersson (1906), the geologist of Otto Nordenskjöld's 1901-1903 Swedish Scientific Expedition to Antarctica, regarded Deception Island to be a single crater, its centre flooded by the incursion of the sea through a breach in the south-east rim. Ferguson (1921, p. 45: *the volcanic ring enclosing the crater)* was of similar opinion. Holtedahl (1929), the geologist of the Norwegian Scientific Expedition to Antarctica, 1927-9, correctly recognized that the island is a *caldera* formed by the subsidence of an original volcano along circular (ring) faults. He distinguished an *Older Volcanic Series* (pre-caldera) including agglomerates and lavas, and a *Younger Volcanic Series* (post-caldera) represented by highly vesicular lavas (correctly: tephra with bombs) of the Kroner Lake area (Whalers Bay), and paid much attention to geomorphological and glaciological features of the island. Holtedahl's views were largely followed by Olsacher (1956) who distinguished a *Serie Volcanica Antigua* and a *Serie Volcanica Moderna* and added many new volcanological and geomorphological observations.

Both Holtedahl and Olsacher assumed that the caldera resulted from the collapse of a single original cone, a view not supported by Hawkes (1961), according to whom it formed by the subsidence of a group of overlapping volcanoes along arcuate and radial faults. Hawkes followed Holtedahl's subdivision of the volcanics on Deception Island, and distinguished the *Pre-caldera Series* (Port Foster Group) and the *Post-caldera Series* (subdivided into the Neptunes Bellows-, the Pendulum Cove-, and the Whalers Bay groups). Hawkes' account on the structure and volcanic succession at Deception Island, supplemented with a geological map, 1:25,000 scale, has become a standard reference to all later workers. Hawkes presented also the first systematic petrographic study of volcanic rocks on Deception Island and summarized the early accounts by Gourdon (1914), Ferguson (1921), and Barth and Holmsen (1939). Casertano (1964) added some new physical and geomorphological observations, while following Hawkes' standard of the Deception Island volcanostratigraphy.

NEW INVESTIGATIONS

The 1967-69-70 renewal of volcanic activity at Deception Island along the northern and eastern margins of the caldera had resulted in dramatic changes in many internal features of the island, including destruction of two scientific stations: the Chilean Base at Pendulum Cove, and the British Base at Whalers Bay. This echoed widely in Antarctic Earth-science community. A long list of papers that followed cover a wide range of subjects, *inter alia*:

(i) The course, geological effects of the eruptions, petrography and geochemistry of the volcanic products (Anonym., 1968; Valenzuela *et al.*, 1968; Baker, 1969a, b, 1970; Baker *et al.*, 1969, 1975; Clapperton, 1969; Everett, 1969; Williams, 1969; Nougier, 1969; Shultz, 1970, 1971, 1972a, b; González-Ferrán & Katsui, 1970; González-Ferrán, 1971; González-Ferrán *et al.*, 1971a, b; Faure *et al.*, 1971; Baker & McReath, 1971a, b; Fourcade, 1971; Fourcade & Viramonte, 1972; Orheim, 1972b; Roobol, 1973, 1979, 1982; Viramonte *et al.*, 1974);

(ii) Glaciology and geomorphology in relation to volcanology of the Deception Island (Kläy & Orheim, 1969; Orheim, 1970, 1972a, 1975; Govorukha, 1973; Igarzabal, 1974; Orheim & Govorukha, 1982).

PRESENT STATE

Deception Island continues to be the centre of volcanological interest in West Antarctica. The main lines of the present research are:

(i) Geochemistry of the magma, petrological differentiation and volcanic evolution (Weaver *et al.*, 1979; Smellie, 1988, 1989, 1990, 1992; Baker, 1990; Martí & Baraldo, 1989, 1990; De Wit *et al.*, 1991; Keller *et al.*, 1992);

(ii) Revision of lithostratigraphy and succession of volcanic events (Birkenmajer, 1987, 1988, 1991a, b, and the present paper);

(iii) Structure and deposits of submerged part of the caldera, by seismoacoustic studies and submarine coring (Kowalewski *et al.*, 1990; Rey *et al.*, 1992);

(iv) Geomorphology (Criado *et al.*, 1992; Risso *et al.*, 1992);

(v) Gravimetry and seismicity (Ortiz *et al.*, 1991a, b), fumarole activity and chemistry (Viramonte *et al.*, 1974) and sea-water chemistry (Elderfield *et al.*, 1977).

BASEMENT OF THE VOLCANO

The Deception Island volcano lies on a submerged platform, part of the South Shetland continental-type shelf (see Ashcroft, 1972; Guterch *et al.*, 1985, 1990; Birkenmajer *et al.*, 1990). Evidence from xenoliths collected from agglomerates of the Foster Group, indicates that this platform includes three main elements:

(1) Aphanitic to amygdaloidal, green to black basalts and yellowish to whitish acidic rocks (Birkenmajer, 1991b) and olivine basalt porphyry (Faure *et al.*, 1971), represent the Antarctic Peninsula Volcanic Group – APVG (magmatic arc: late Mesozoic - ?earliest Tertiary);

(2) Quartz-biotite diorite (Olsacher, 1956, pp. 50-52; Hawkes, 1961, p. 24), quartz-hornblende diorite, olivine-gabbro porphyry, diabasic gabbro and porphyritic diabasic olivine gabbro (Faure *et al.*, 1971; Birkenmajer, 1991b) represent the Andean Intrusive Suite – AIS (magmatic arc: late Mesozoic - ?earliest Tertiary);

(3) Pelitic to fine-psammitic volcanogenic sedimentary rocks (bentonitic claystone, tuffite, palagonitic tuff) with Early Eocene coccoliths (Birkenmajer & Dudziak, 1991), represent marine sedimentary cover of the magmatic arc.

The evidence obtained from the xenoliths gives a clear indication that the pre-Eocene basement of the Deception Island volcano is similar in rock composition to the nearby Livingston Island, where the APVG and AIS rocks are the most important ones (*cf.* Fleming & Thomson, 1979). There is so far no evidence from xenoliths for the presence in the basement of Deception Island of siliciclastic deposits of the Miers Bluff Formation (?Permo-Triassic) known from Hurd Peninsula on Livingston Island (*op. cit.*). In spite of this, the basement of the volcano clearly belongs to the continental-type crust of the South Shetland Islands, as also follows from the DSS modelling by Guterch *et al.* (1985, 1990). On the contrary, Smellie *et al.* (1992) prefer a *broadly oceanic "basement", possibly containing detached slivers of older granitic crust.*

AGE OF THE VOLCANO

According to Shultz (1972a), based on radiometric dating not exceeding 100,000 y, the volcano is Late Pleistocene to Holocene in age. Orheim (1972a, 1975) gave the evidence from glacier ice for a 200-year record of volcanic activity at Deception Island. All exposed rocks have normal magnetic polarity (Brunhes period), indicating that they are younger than 0.7 Ma (Valencio *et al.*, 1979). This age conclusion is also shared by Smellie (1988, 1990).

However, one of the stratigraphically lowest lavas (Port Foster Group) was K-Ar dated at 150,000 ± 46,000 y suggesting that the volcano was built since 0.2 Ma (Keller *et al.*, 1992), a view supporting that of Shultz (see above).

PREVIOUS LITHOSTRATIGRAPHIC STANDARDS

Holtedahl's (1929) subdivision of the volcanics on Deception Island into older (pre-caldera) and younger (post-caldera) complexes is still widely accepted by volcanologists working there, however with very widely varying context:

(1) Hawkes (1961) distinguished: (i) the *Pre-caldera Series*, i.e. the Port Foster Group (including Outer Coast tuff, Fumarole Bay volcanics, lavas and agglomerates of Macaroni Point and vent agglomerate of Cathedral Crags), and (ii) the *Post-caldera Series*, subdivided into the Neptunes Bellows-, the Pendulum Cove-, and the Whalers Bay groups;

(2) González-Ferrán and his co-workers (González-Ferrán & Katsui, 1970; González-Ferrán, 1971; González-Ferrán *et al.*, 1971a, b) included to the *serie pre-caldera* three units: (i) lavas and pyroclastics of olivine-basalts and andesites – representing the Foster volcano; (ii) basaltic-andesite tuffs and agglomerates – representing parasitic cones of Neptune Bellows (Fuelles de Neptuno); (iii) andesitic lapilli tuffs. These three units are widely distributed along the outer and middle parts of the island's ring (González-Ferrán & Katsui, 1970, fig. 23). The *serie post-caldera* includes cinder cones, lapilli,

bombs, maars, lava flows of the aa and blocky types, of andesitic and olivine-basalt composition;

(3) Baker *et al.* (1975) used Hawkes' standard with some modification. (i) The pre-caldera stage (approximate equivalent of the Port Foster Gp of Hawkes) included: the stage of primary strato-volcano ("outer coast tuff" and the rock-units at Stonethrow Ridge and Telefon Ridge); the parasitic cones on primary volcano (Macaroni Point and Baily Head sites); and the pyroclast flows preceding caldera subsidence (Cathedral Crags and Fumarole Bay sites). The main episode of the caldera collapse preceded the "earlier post-caldera lavas and scoria" (South East Point and Entrance Point sites – equivalent to the Neptunes Bellows Gp of Hawkes). (ii) There followed the "later post-caldera eruptions" (pyroclastic cones, e.g. Crimson Hill, Wensleydale Beacon – equivalents to the Pendulum Cove Gp of Hawkes; and lava flows, e.g. Kendall Terrace and Stonethrow Ridge – equivalents of the Whalers Bay Gp of Hawkes). (iii) Finally, there was a series of historical eruptions of 1842 (Mt Kirkwood), post-1842, pre-1957 (Kroner Lake etc., Roobol, 1973), 1912–17 (ice record by Orheim, 1972b), 1967 (Telefon Bay), 1969 (Mt Pond) and 1970 (Telefon Bay);

(4) Baker (1990) simplified his former standard (of 1975) and distinguished: (i) the pre-caldera pyroclastic deposits (yellow palagonite tuffs and agglomerates) with interspersed lava flows and red scoria horizons; (ii) the syn-caldera pyroclastic flows; (iii) the post-caldera lavas and pyroclastic deposits.

(5) Smellie (1988, 1989) modified earlier standards of Hawkes (1961), Baker *et al.* (1975) and Baker (1990), with preference for a bipartite subdivision: (i) the "pre-caldera deposits" consist of pyroclastic rocks, lavas and "outer coast tuff" (= mass flow deposits), and (ii) the "post caldera deposits" consist of the "early tuff cone deposits", fissure-erupted Strombolian scoria and lava, late tuff cone and maar deposits and the Recent epiclastic sediments and moraines;

(6) Martí and Baraldo (1992) distinguished: (i) the pre-caldera volcanics (including the "basaltic shield formation" and the "yellow tuff formation"); and (ii) the post-caldera volcanics. Their subdivision into the pre-caldera and post-caldera units differs, however, in rock-types content from that of Hawkes (1961), Baker *et al.* (1975) and Smellie (1988, 1989).

NEW VOLCANOSTRATIGRAPHIC STANDARD

The new volcanostratigraphic standard (Birkenmajer, 1991b; Tab. 1) includes formal lithostratigraphic units of group and formation ranks, wherever possible associated with related volcanic morphological and structural features (fissures, craters, cones etc. – Tab. 1). The petrographic names used (Tabs 1, 2) are based on geochemical study by Prof. Martin Fisk and Mr. Randall A. Keller (Oregon State University, Institute of Oceanography, Corvallis, Oregon, USA) of the samples collected by the present author in 1985 and 1988, and by R. A. Keller in 1991 (Birkenmajer, 1991a, b; Keller *et al.*, 1992).

Table 1

Lithostratigraphic standard for the volcanic succession at Deception Island.
A – andesite; B – basalt; BA – basaltic andesite; TB – trachybasalt; TD – trachydacite; MIX – mixed petrology. Petrographic names after R. A. Keller and M. R. Fisk, except for the asterisked ones which are after Hawkes (1961). Vertical hatching denotes major breaks in the volcanic succession

GROUP	FORMATION	PHASE	FORM	PRINCIPAL PRODUCTS	COLOUR	PETR. TYPE	DATE	VOLC. CYCLE	STAGE
HAWKES (HG)	TELEFON (TF)	GONZÁLEZ (TG)	MAARS	TEPHRA (+ BOMBS & PUMICE)	GREY-GREEN	A	1970	II	POST - CALDERA
		POND (TP)	FISSURE ERUPTIONS	TEPHRA (+ BOMBS) LAVA (SCORIA)	BLACK RED	A	1969		
		YELCHO (TY)	CONES	TEPHRA	GREEN-GREY	A	1967		
	KIRKWOOD (KF)	KRONER (KR)	MAAR	TEPHRA	BLACK	B*	1912-1829		
		KIRKWOOD (KK)	FISSURE ERUPTIONS	LAVA (SCORIA) TEPHRA (+ BOMBS)	RED BLACK	B*	1842		
	CASCO (CaF)	EMERALD (CaE)	CONE WITH CRATER	LAVA, TEPHRA	GREY RED	?BA	pre-1829		
		CASCO (CaC)	CONES WITH CRATERS	TEPHRA (+ BOMBS)	BLACK	BA	-"-		
	CHACAO (ChF)	KENDALL (ChK)	MAARS	TEPHRA	DARK-GREY	(MIX)	-"-		
		CHACAO (ChC)	CONES WITH CRATERS	TEPHRA (+ BOMBS)	GREY-GREEN	BA	-"-		
	COLLINS (CF)	(CF_2)	CONES WITH CRATERS	TEPHRA	GREY-GREEN	(MIX)	-"-	I	
		(CF_1)	LAVA FLOWS	LAVA (+ TEPHRA)	GREY, BLUISH, BLACK, RED	TD	-"-		
	RONALD (RF)	(RF_2)	PLUG	PLUG (+ LAVA)	GREY, BLUISH	TD	-"-		
		(RF_1)	LAVA FLOW	LAVA	GREY, BLUISH	TD	-"-		
			radial faulting	— caldera collapse					SYN-CALDERA
	MURATURE (MF)		DESTROYED RING CONES	TEPHRA (+ BOMBS)	GREY, GREEN	A	-"-		
			ring faulting	— caldera collapse					
FOSTER	WINDOW (FG_4)		DYKES	DYKE (LAVA)	GREY TO BLACK	TB	LATE-PLEISTOCENE?-HOLOCENE		PRE-CALDERA
	STONETHROW (FG_3)		STRATOCONE	LAVA (+ SCORIA)	GREY, BLACK, RED	BA; B			
	CATHEDRAL (FG_2)			TEPHRA (+ BOMBS)	GREY, YELLOW WEATHERED	(MIX)			
	ENTRANCE (FG_1)			LAVA (+ SCORIA)	GREY, BLACK, RED	BA; ?B			

BASEMENT: EOCENE MARINE SEDIMENTS UPON LATE MESOZOIC TO EARLY TERTIARY VOLCANICS AND INTRUSIVES

Two volcanostratigraphic groups are distinguished (Birkenmajer, 1991b): the Foster Group (older) and the Hawkes Group (younger). The Foster Group includes four formations: the Entrance Formation (oldest); the Cathedral Formation; the Stonethrow Formation; and the Window Formation (youngest). The Hawkes Group includes seven formations: the Murature Formation (oldest); the Ronald Formation; the Collins Formation; the Chacao Formation; the Casco Formation; the Kirkwood Formation; and the Telefon Formation (youngest). Their areal distribution is shown in Fig. 3, the site names used (with synonyms) are listed in Tab. 3 and shown in Figs 3, 4.

Table 2

List of samples examined (for abbreviations see Tab. 1). Petrographic determination by R. A. Keller and M. R. Fisk

Sample #	Rock type	Location	Formation/phase
A-1050	A (bomb)	Telefon Bay	TP
A-1060	A (bomb)	Airstrip Crater	TP
A-1066	A (tephra)	Yelcho Hill	TY
A-1067	A (tephra)	Yelcho Hill	TY
A-1084	BA (lapilli tuff)	Punta Casco	CaC
A-1085b	BA (tephra)	Chacao Cone	ChC
A-1075	TD (lava)	Collins Point	CF_1
A-1079	TD (lava)	Lava Point	CF_1
A-1057	TD (plug)	Ronald Hill	RF_2
A-1055	TD (lava)	Ronald Hill	RF_1
A-1088	A (lapilli tuff)	Stonethrow Ridge	MF
A-1051	TB (dyke)	Cathedral Crags	FG_4
A-1087	BA (red scoria)	Stonetherow Ridge	FG_3
A-1063	BA (upper lava)	Red Crag	FG_3
A-1065	BA (bomb)	Red Crag	FG_3
A-1048	B (grey lava)	Telefon Ridge	FG_3
A-1049	BA (red scoria)	Telefon Ridge	FG_3
A-1081	BA (tephra)	Lava Point	FG_3
A-1082	BA (lava)	Lava Point	FG_3
A-1092	BA (lower lava)	Entrance Point	FG_1

The volcanostratigraphic units of formation rank are the main rock-units distinguished. Some formations are further subdivided (informally) into successive volcanic phases (Tab. 1). The pre-caldera, syn-caldera and post-caldera units are treated as informal names; they are retained to indicate possible relation of particular formations and phases to the main volcano-structural events at Deception Island. However, they should not be treated as formal rock-units.

Table 3

Deception Island: Site names with synonyms. * –. new names; d. – destroyed base.
Main name sources: Holtedahl (1929); Olsacher (1956); Hawkes (1961); Valenzuela *et al.* (1968); Baker (1969a, b); Nougier (1969); González-Ferrán & Katsui (1970); González-Ferrán (1971); Baker & McReath (1971a, b); Baker *et al.* (1969, 1975); Fourcade & Viramonte (1972); Igarzabal (1974); Antarctic Pilot (1974)

Name (Synonym and/or misspelling)	Figure
*Airstrip Crater	3, 4, 16
Argentine Base	3, 4, 14, 15, 24B-D
Baily Head (Bailey H.; Punta Este; Punta Rancho)	3, 4, 9A, 24A-D
Black Glacier (Glaciar Buen Tiempo)	3, 4, 16
Buen Tiempo, Punta	3, 4
Casco, Punta	3, 4, 14, 15, 19C, 21, 24D
Cathedral Crags	3-6, 8, 16, 17C
Chacao Crater, Cone (Cross Hill)	3, 4, 18A, B, 24D, 25
Chacao, Punta	18B, 25
Chile, Mount (Monte; Mte Estanque)	3, 4, 12
Chilean (Chile) Base (Station) (d.)	11A, 12, 24B, C
Collins Point (Punta Fontana)	3, 4, 17A, B, 19A, B, 24D
Crater Lake (Jade Crater Lake)	3, 4, 22, 24B-D
Crimson Hill	3, 4, 11A, 12, 24B-D
Cross Hill (Mte de la Laguna; Chacao Crater, Cone)	3. 4. 24B-D
*Eastern Claw	3, 4
*Emerald Lake (Lago Irízar, *partim*)	15
Entrance Point	3, 4, 24B-D
Falsa Punta Rancho	3, 4
Foster, Port	3, 4, 11A, 12, 13, 17B, C, 21, 24B-D
Fumarole Bay (Bahía 1° de Mayo)	3, 4, 13, 24B-D
Galíndez, Monte	3, 4
Goddard Hill (Bynon *vel* Binon H.)	3, 4, 25, 26B
*González Harbour	3, 4, 25
*Green Crag	6
*Hawkes Glacier	3, 4, 9A
*High Window	6, 9B
*Holtedahl Hill	3, 4, 10A, B
INACH Crater (= Sealers Harbour)	3, 4, 20A, B, 25
*Irízar Crater	3, 4
*Irízar, Lagoon (Lago I.)	14, 15

Name (Synonym and/or misspelling)	Figure
Irízar, Monte	3, 4, 14, 15, 21, 22, 26A, B
*Jade Crater Lake (Crater Lake)	3, 4, 22, 24B-D
*Kendall Crater	3, 4
*Kendall Point	3, 4, 26B
Kendall Terrace	3, 4
Kirkwood, Mount (Mte Goyena; Mt David)	3, 4, 11C, 17B, 21, 22, 24B-D, 26B
Kroner Lake (Laguna Verde)	3, 4, 24B-D
Lava Point (Punta Negra)	3, 4, 17B, C, 21, 24D
Låvebrua Islet (L. Island; Islote Chaco)	3, 4, 8, 11C, 24B-D
Macaroni Point (Punta Noreste)	3, 4, 24B-D
Murature, Punta	3, 4, 13, 18B, C, 24D
Neptunes Bellows (Fuelles de Neptuno)	3, 4, 8, 17A-C, 19A, 24B-D
Neptunes Window	6
*North Point	3, 4
New Rock	3, 4, 24B-D, 26A-C
*Oscar Lakes (Lake)	3, 4, 11B, 25
Pendulum Cove	3, 4, 11A, 24A-D
Penfold Point	4
*Perchuć Cone	3, 4, 23
Petes Pillar	8
Pond, Mount (Mte Campbell; Mt Pound)	3, 4, 10A, B, 16, 24A-D
*Red Crag	9B
*Red Spur	12
Relict Lake	24B
Rinconada	25
Ronald Hill	3, 4, 11D, 16, 24B-D
Sail Rock	26D
Sealers Harbour (INACH Crater, *partim*)	20A, 24A-C, 25
Sealers Point	3, 4, 20A, B, 24B-D, 25
Sewing Machine Needles	4, 9A
South East Point (Punta Sudeste)	3, 4, 24B-D
South Point (Punta Sur)	3, 4, 11C
*South West Point	3, 4, 26B
Stonethrow Ridge (Mte Beazley & Mte Champaquí)	3, 4, 13, 24B-D, 26A, B
Telefon Bay (Bahía Telefono)	3, 4, 18A, 20A, 24B
*Telefon Pass	26B
Telefon Ridge (Mte Uritorco & Mte Achala)	3, 4, 11B, 24B-D, 25, 26B

Name (Synonym and/or misspelling)	Figure
Tuff Beach	4, 17C
Twin Crater	3, 4, 17C
U.K. Base (British Base) (d.)	24B, C
Vapour Col	3, 4, 14, 15, 21, 26A, B
*Vapour Point	3, 4, 26A, B
Wensleydale Beacon	3, 4, 13, 18B, 24B-D
*Wensleydale Valley	3, 4
*West Point	3, 4, 26A, B
*Western Claw	3, 4
Whalers Bay (Caleta Balleneros)	3-6, 8, 10B, C, 24B-D
Yelcho Hill	3, 4, 24D, 25
Yelcho Island (Isla Y.; Marinero Suárez)	24C

FOSTER GROUP (FG)

(redefined unit)

Name and history: After Port Foster (Figs 3, 4). Name introduced by Hawkes (1961: Port Foster Group).

Subdivision: The Foster Group is subdivided into four formations: the Entrance Fm.; the Cathedral Fm.; the Stonethrow Fm.; and the Window Fm. (Tab. 1).

Petrography and structure: The lavas are predominantly basaltic andesite and, subordinately, basaltic in character (Tab. 2). The flows are up to a score or so metres thick, with grey to black lava in the middle, reddening at scoriaceous tops and bottom flow breccias. The lavas alternate with vivid-red, sometimes also yellow pyroclastics of variable thickness, containing also volcanic bombs (Entrance and Stonethrow fms), sometimes interfinger or alternate with grey, yellow-weathered explosion breccias and large-scale cross-bedded agglomerates (mainly in the Stonethrow Fm., less frequently in the Entrance Fm.). A thick, large-scale cross-bedded pyroclastic unit (with volcanic bombs) grading from coarse to fine agglomerate to lapilli-tuff unit, which occurs in the middle of the Foster Group, is distinguished as the Cathedral Formation. It intertongues downward (Entrance Fm.) and upward (Stonethrow Fm.) with the basaltic lavas.

The youngest phase of volcanic activity attributed to the Foster Group is represented by infrequent, thin basic dykes (Window Fm.) cutting through the older three formations; they probably intruded during initial phase of caldera collapse. Radial and ring faults post-dating the Foster Group are well visible in many parts of the island (e.g., Figs 3, 5, 9B, 11, 13-15).

Thickness: The cumulative thickness of the Foster Group, as exposed above sea level, is between 400 and 600 m.

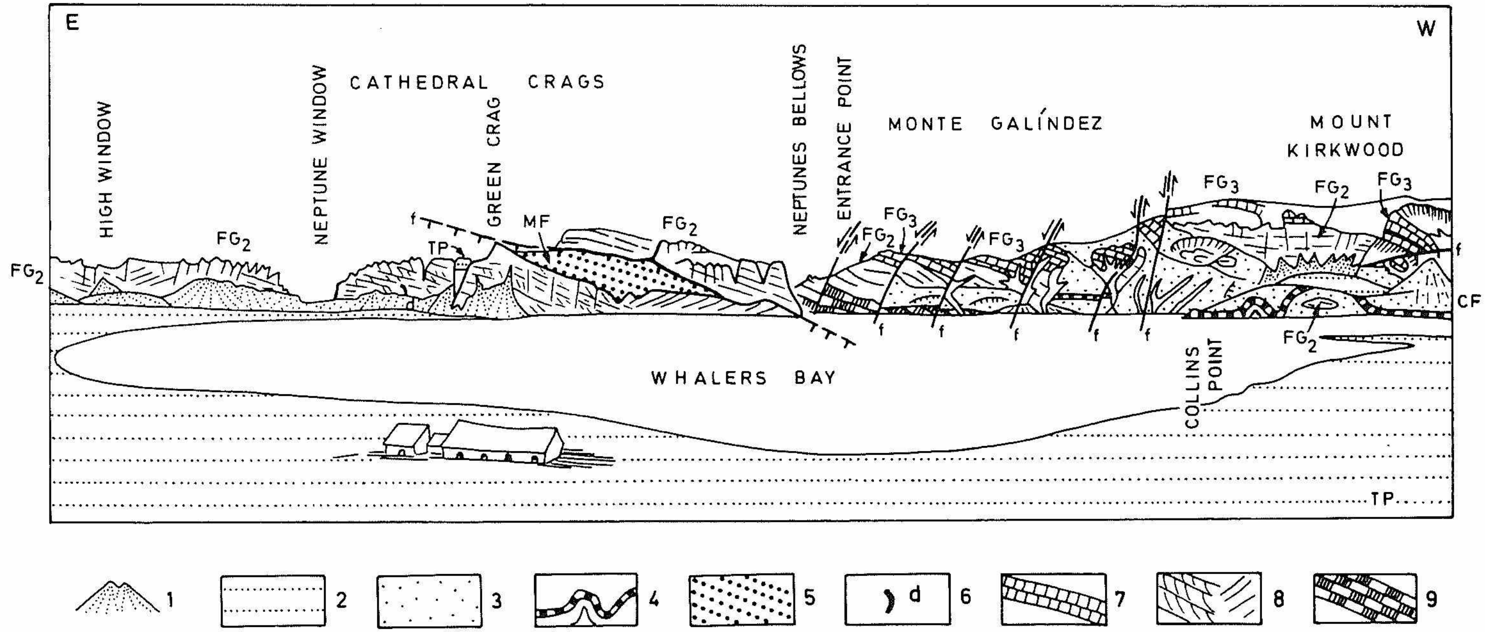

Fig. 5 Geological panorama from the destroyed UK Base (Magistrate house) at Whalers Bay. *1* – talus, talus cones; *2* – Telefon Fm., Pond phase (*TP* - tuff); *3*, *4* – Collins Fm. (*3* – tuff; *4* – lava); *5* – Murature Fm.; *6* – Window Fom. (*d* – dyke); *7* – Stonethrow Fm. (*FG3*: lavas); *8* – Cathedral Fm. (*FG2*: agglomerates); *9* – Entrance Fm. (*FG1*: lavas and tuffs); *10* – radial faults; *11* – ring faults; *12* – escarpments, crater rims

Age: The age of the Foster Group is post-Eocene, as indicated by coccolith remains found in clasts of marine pelitic to fine-psammitic volcanogenic deposits collected from the Cathedral Fm. agglomerates at Whalers Bay (Birkenmajer & Dudziak, 1991). No traces of Oligocene through Pliocene or younger fossiliferous clasts have been found in these agglomerates so far. One of the lowest lava flows of the Foster Group yielded a K-Ar age of 150,000 ± 46,000 years (Keller *et al.*, 1992), thus indicating a Late Pleistocene age of the Group.

Distribution: The Foster Group is distributed all over the island, forming outer and middle parts of its ring (Fig. 3). Large blocks of the Group are often immersed in post-caldera volcanics along the inner margin of the ring (e.g., Figs 3, 17B, 22).

Remarks:

(i) The "older volcanic series" of Holtedahl (1929) generally correlates with the Foster Group *sensu mihi*: his "yellow tuffs" (agglomerates) at Cathedral Crags, Baily Head, Ronald Hill, at Entrance Point and west of it, and at Mte Irízar *(op. cit.*, figs 13–15: T), belong to the Cathedral Fm.; his "compact or moderately vesicular dark-coloured lava" at South East Point and north of it (*op. cit.*, fig. 13, upper figure) belongs to the Stonethrow Fm. (at South East Point and Baily Head, Holtedahl correctly marks "probable faults", and his map – fig. 13, 1:50,000 scale – also suggests superposition of the lavas upon "yellow tuffs" at South East Point what is true – see this paper Fig. 9B); his "red beds with volcanic bombs" from Ronald Hill (*op. cit.*, fig. 15: BL) also belong to the Stonethrow Fm. (see my Figs 11D, 16); the lavas at Collins Point (*op. cit.*, fig. 13, upper figure) and at Ronald Hill (*op. cit.*, fig. 13, upper figure; figs 14, 15: L) attributed by Holtedahl to the "older volcanic series", in my interpretation belong to the Ronald Fm. which is younger than the Foster Group (see Figs 11D, 16);

(ii) Olsacher (1956, fig. 3) distinguished within his "serie volcanica antigua": lower andesites and basalts (corresponding mainly to the Entrance and the Stonethrow fms of the present paper); yellow tuffs in the middle (mainly Cathedral Fm.); and stratified tuffs at the top (partly Cathedral and Stonethrow fms, mainly Murature Fm. and younger formations). His "serie volcanica moderna" (basalts) includes lavas of the Foster Group and of the Collins, Chacao and Casco fms as well;

(iii) The Port Foster Group (outer coast tuff; Fumarole Bay volcanics; Telefon Bay volcanics; lavas and agglomerates of Macaroni Point; vent agglomerate of Cathedral Crags); a part of the Neptunes Bellows Group (at Vapour Col, Entrance Point and South East Point); a part of the Pendulum Cove Group (at Mt Kirkwood); and a part of the Whalers Bay Group (at Telefon Ridge and Stonethrow Ridge) of Hawkes (1961) belong to the Foster Group of the present standard;

(iv) The pre-caldera series (lavas and agglomerates) of González-Ferrán & Katsui (1970, fig. 23), belongs to my Foster Group (pre-caldera), exclusively of the lapilli-tuff which in the present interpretation belongs to the Murature Formation (syn-caldera);

(v) Baker *et al.* (1975, fig. 2) include to the "pre-caldera pyroclasts and lava flows": the rocks at Baily Head (= Cathedral Fm.), Låvebrua Islet and South Point (= Cathedral Fm.); slope exposures above Collins Point (= Cathedral Fm.); coastal exposures between Vapour Col and Macaroni Point (= Cathedral Fm. and Stonethrow Fm.); exposures at Stonethrow Ridge (= Stonethrow Fm.) and Telefon Ridge (= Stonethrow Fm.). They include the Cathedral Crags agglomerate (= Cathedral Fm.) to the "syn-caldera pumiceous tuffs and agglomerates (pyroclast flows)", and the rocks between Entrance Point and Falsa Punta Rancho (= all four formations of the Foster Group and younger formations) and at South East Point (= Cathedral Fm. and Stonethrow Fm.) – to the "early post-caldera lavas and pyroclasts";

(vi) The pre-caldera pyroclastic deposits and lavas, the syn-caldera pyroclastic flows (= Cathedral Fm.), and a part of the post-caldera lavas and pyroclastic deposits of Baker (1990, Fig. D.2.1) belong to the Foster Group of the present standard (*cf.* Fig. 3);

(vii) The "pre-caldera deposits" (pyroclastic rocks, lavas, and "outer coast tuff", i.e. mass flow deposits), a part of the "early tuff cone deposits", a major part of the "fissure-erupted Strombolian scoria and lavas", and a part of the "late tuff and maar deposits" (post-caldera) of Smellie (1988, Fig. 1; 1989, Fig. 21.1) belong to the Foster Group of the present standard;

(viii) The "pre-caldera deposits", and a part of the "post-caldera deposits" of Martí and Baraldo (1990, Fig. 2), also belong to the Foster Group of the present standard;

(ix) Faure *et al.* (1971) report from the Foster Group *sensu mihi* the following rock types: autobrecciated microvesicular partially palagonized basalt glass, Cathedral Crags (= Cathedral Fm.); slightly porphyritic high-Al olivine basalt lava, S end of Telefon Ridge (= Stonethrow Fm.); high-Al olivine basaltic andesite flow, SE Point (= Stonethrow Fm.).

Entrance Formation (FG_1)

(new unit)

Name: After Entrance Point, Neptunes Bellows, where the formation is well exposed (Figs 3 – 5). Name introduced by Birkenmajer (1991a, b).

Petrography and structure: The formation includes basaltic and basaltic andesite lavas with subordinate agglomerate, lava-breccia and tuff interlayers. The colouration of the lavas, breccias and tuffs is vivid red to black, that of agglomerates – yellowish if weathered; there occur also yellowish tuff intercalations. The rocks intertongue upwards with the Cathedral Formation agglomerates. They are involved in radial and ring faulting (Figs 3, 5, 11A, C, D, 12).

Selected site description:

(i) At steep southern coast of Neptunes Bellows (Fig. 3) crop out almost flat-lying dark-grey and red ropy lavas alternating with vivid-red tuffs (Entrance Fm.); they are overlain by yellow-weathered agglomerates (Cathedral Fm.). Both formations are densely faulted (Figs 3, 5);

(ii) At Pendulum Cove, the Entrance Formation is exposed at Red Spur and Crimson Hill (Figs 11A, 12). The formation consists of red scoriaceous lava and brown-red massive lava at Crimson Hill, and of red lava alternating with black tephra and yellow agglomerate at Red Spur. At Red Spur, the lavas are overlain by yellow-weathered agglomerates showing large-scale foresets (Cathedral Fm.) inclined towards the south, at Crimson Hill they are faulted against the same agglomerates of the Cathedral Fm. and against stratified cemented lapilli tuffs of the Murature Fm.;

(iii) Between South Point and South West Point (Figs 3, 11C), crop out at sea level crimson-red lavas (Entrance Fm.) locally overlain by yellow agglomerates (Cathedral Fm.), and by semi-consolidated tuffs (Collins Fm., CF_2);

Thickness: The maximum thickness of the formation exceeds 150 m (base not known).

Distribution: The best exposures of the Entrance Formation are at Entrance Point and southern coast of Neptunes Bellows (Figs 3, 5), and at Pendulum Cove (Figs 11A, 12).

Remarks:

(i) Hawkes (1961: geol. map) attributed the rocks at Entrance Point (and also of Falsa Punta Rancho) to the post-caldera Neptunes Bellows Group (vent agglomerate, tuff, lava). In the same area, González-Ferrán & Katsui (1970, fig. 23) distinguished tuffs and basaltic-andesite agglomerates of the pre-caldera parasitic cones *(conos parásitos de Neptuno)*, and at the eastern slope of Mte Galíndez – olivine-basalt and andesite lavas and pyroclastics of the Foster volcano (pre-caldera);

(ii) The exposure at Entrance Point illustrated by Baker *et al.* (1975, Fig. 4) shows lava flows alternating with red scoria and yellow tuff (= Entrance Fm.), faulted and intruded by thin dykes (= Window Fm.);

(iii) Smellie (1988, fig. 1; 1989, fig.21.1 and loc. 1) includes the Entrance Fm. lavas and tuffs partly to the pre-caldera, but mainly to the post-caldera units.

Cathedral Formation (FG_2)

(new unit)

Name: After Cathedral Crags at Whalers Bay (Figs 3-8). Name introduced by Birkenmajer (1991a, b).

Petrography and structure: Grey to black if fresh, yellow-weathered, coarse to fine agglomerates often showing large-scale cross-bedding (slope bedding). They consist mainly of basaltic lava fragments up to 1 m in

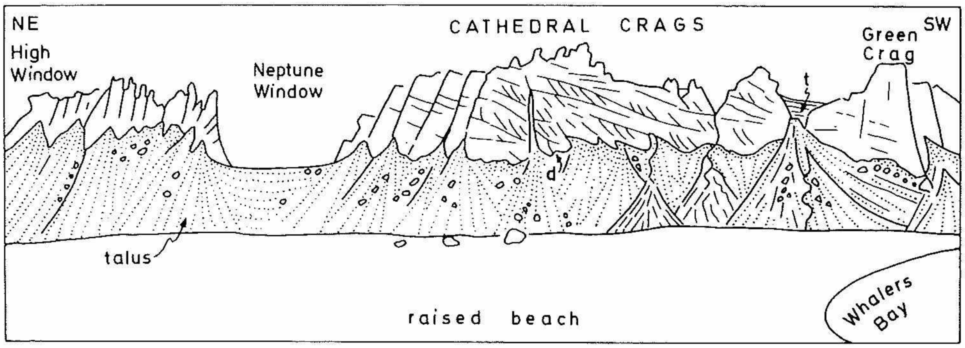

Fig. 6 Cathedral Crags, exposure of large-scale cross-bedded agglomerates of the Cathedral Fm. *d* – trachybasalt dyke (Window Fm.); *t* – lapilli tuffs of the Murature Fm. covered by tuff of the Telefon Fm. (Pond phase). After Birkenmajer (1991b)

diameter, but usually of cobble-to-pebble size through coarse to fine lapilli grades, and contain also twisted basaltic bombs.

There occur also xenoliths of older rocks: (i) Eocene coccolith-bearing palagonitic tuff, tuffite and bentonitic claystone collected at Whalers Bay (Birkenmajer & Dudziak, 1991); (ii) green to black aphanitic to amygdaloidal basalts and yellowish to whitish acidic volcanic rocks (APVG: late Mesozoic - ?earliest Tertiary); (iii) gabbroic rocks (AIS: late Mesozoic - ?earliest Tertiary) collected at Twin Crater (Birkenmajer, 1991b); quartz-biotite diorite (same site and unit) collected by Olsacher (1956, pp. 50-52; see also Hawkes, 1961, p. 24). The Cathedral Fm. is involved in radial and ring faulting, and locally intruded by thin trachybasalt (and basaltic-andesitic) dykes (Window Fm.).

Selected site description:

(i) At Cathedral Crags and Holtedahl Hill, Whalers Bay (Figs 6, 7, 8B, 9B, 10A-D), the agglomerates are dark-grey to black on freshly exposed surfaces (Fig. 8B), and intensely yellow if weathered. The size of clasts varies between lapilli tuff and blocky agglomerate. They consist of: grey basaltic lava (most frequent, Entrance Fm. type), 1-10 cm, sometimes up to 1 m in size; red scoriaceous lava (*dtto*, less frequent) and yellow consolidated agglomerate (Cathedral Fm. type) up to 15 cm in size. There are also less frequent twisted basaltic bombs. Large-scale cross-bedding dips 30-35° due NW at Holtedahl Hill (Fig. 10A, C, D), with larger clasts often ignoring stratification and producing impact structures (Fig. 10D). At Cathedral Hills (Figs 6, 7), large-scale foresets dip at angles of 45-60° due SW; they are arranged in mega-cross-sets separated by erosional surfaces which truncate the foresets, inclined at angles of 15-20° due SW;

(ii) At Pendulum Cove, at Red Spur and Crimson Hill (Figs 11A, 12), the Cathedral Fm. consists of hard, yellow-weathered agglomerate, with well recognizable large-scale foresets dipping at 20-30° due S (at Red Spur);

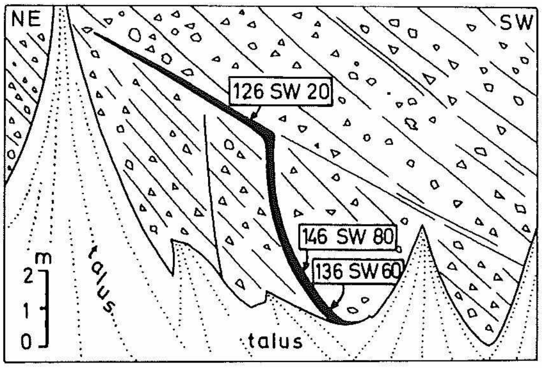

Fig. 7 Trachybasalt dyke (Window Fm.) at Cathedral Crags intruded into large-scale cross-bedded agglomerates of the Cathedral Fm. Strikes (azimuths) and dips of the dyke indicated. For location – see Fig. 6

(iii) At Låvebrua Islet (319 ft high), there occur stratified, locally contorted yellow agglomerates (black at fresh-exposed surfaces) dipping 25-30° due N and NE. The site may represent a fragment of parasitic cone (Fig. 8A) formed at the SE slope of the Foster volcano, at the time of the Cathedral Fm. This site, together with the next one (New Rock), mark the outer circumference of the Deception Island volcano during the time of the Cathedral Fm.; the radius

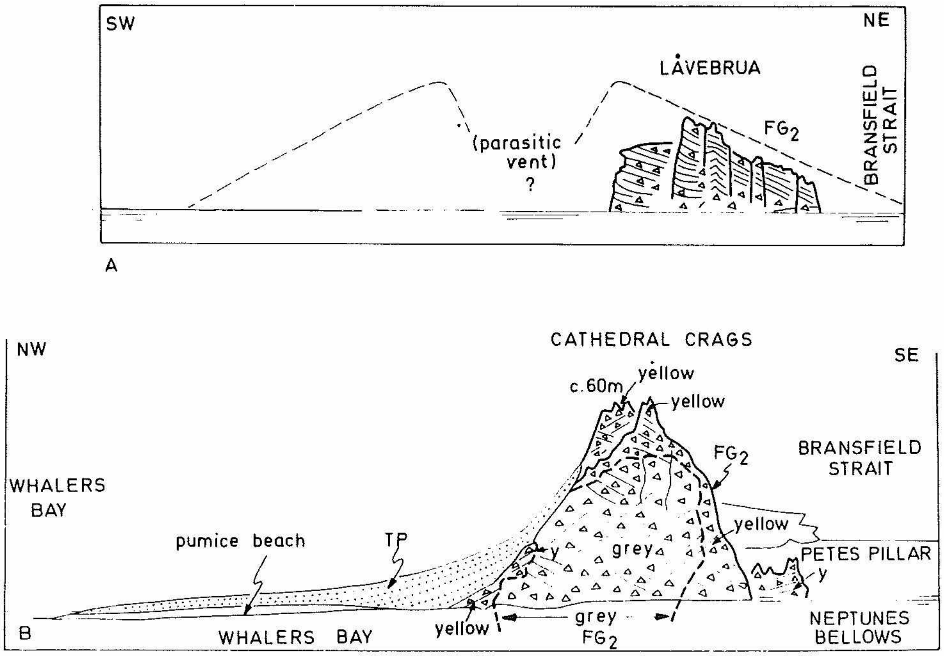

Fig. 8 Large-scale cross-bedded agglomerates of the Cathedral Fm. at Låvebrua Islet (A) and at Whalers Bay (B). Yellow-weathered zone is restricted to outer parts of the exposure; the agglomerates are grey to black at freshly exposed surfaces. *TP* – Telefon Fm. (Pond phase: tuffs)

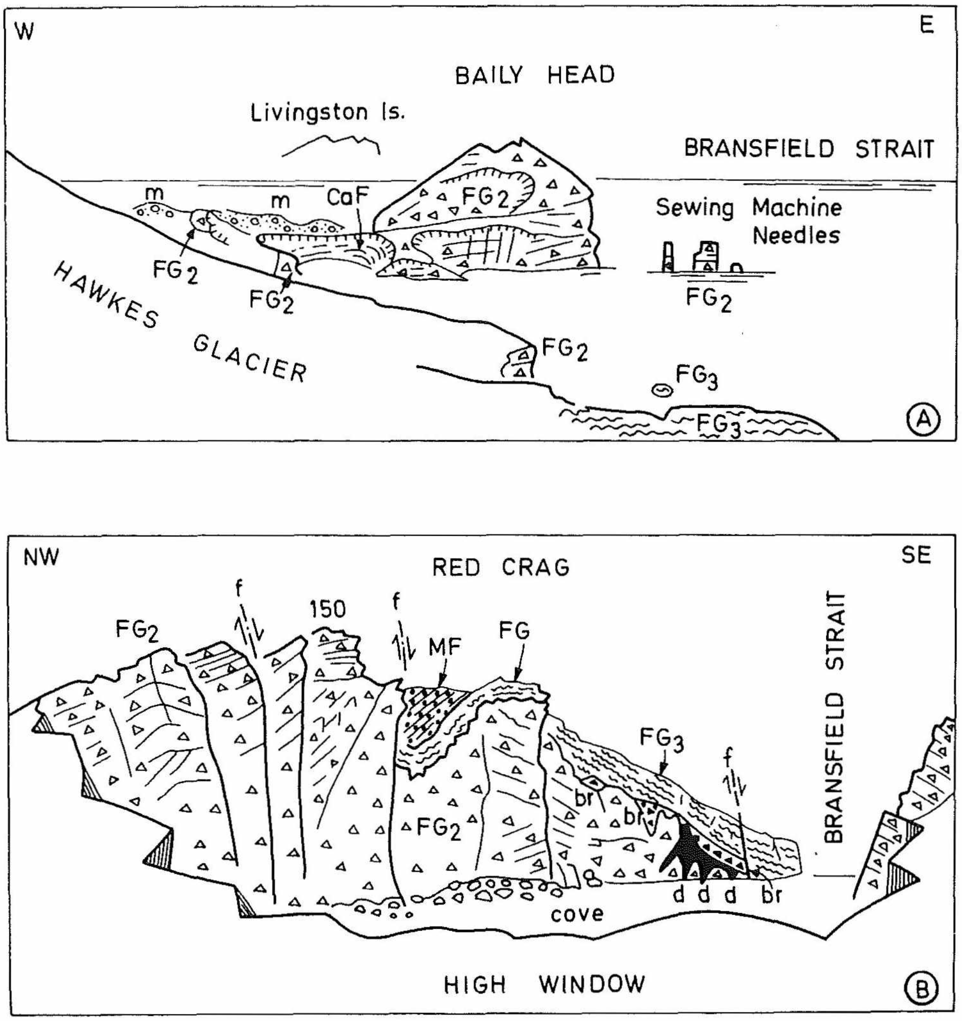

Fig. 9 A. Geological panorama of Baily Head. B. Geological panorama of Red Crag, as seen from High Window, Cathedral Crags (see Figs 3, 6). *FG2* – Cathedral Fm. (agglomerates); *FG3* – Stonethrow Fm. (basaltic lavas); *MF* – Murature Fm. (lapilli tuffs); *CaF* – Casco Fm. craters; *br* – volcanic breccia; *d* – basaltic dykes post-dating FG2 (feeder veins to FG3 ?); *f* – faults; *m* – moraine

of the Foster volcano was at least 1 km larger than of the present Deception Island;

(iv) New Rock, a lonely stack situated 1 km offshore south-east of Deception Island (Figs 3, 26B), consists of coarse, banded agglomerate, black at fresh surfaces, yellowish-weathered. The banding steeply dips at 60° or more due SE suggesting tectonic disturbance;

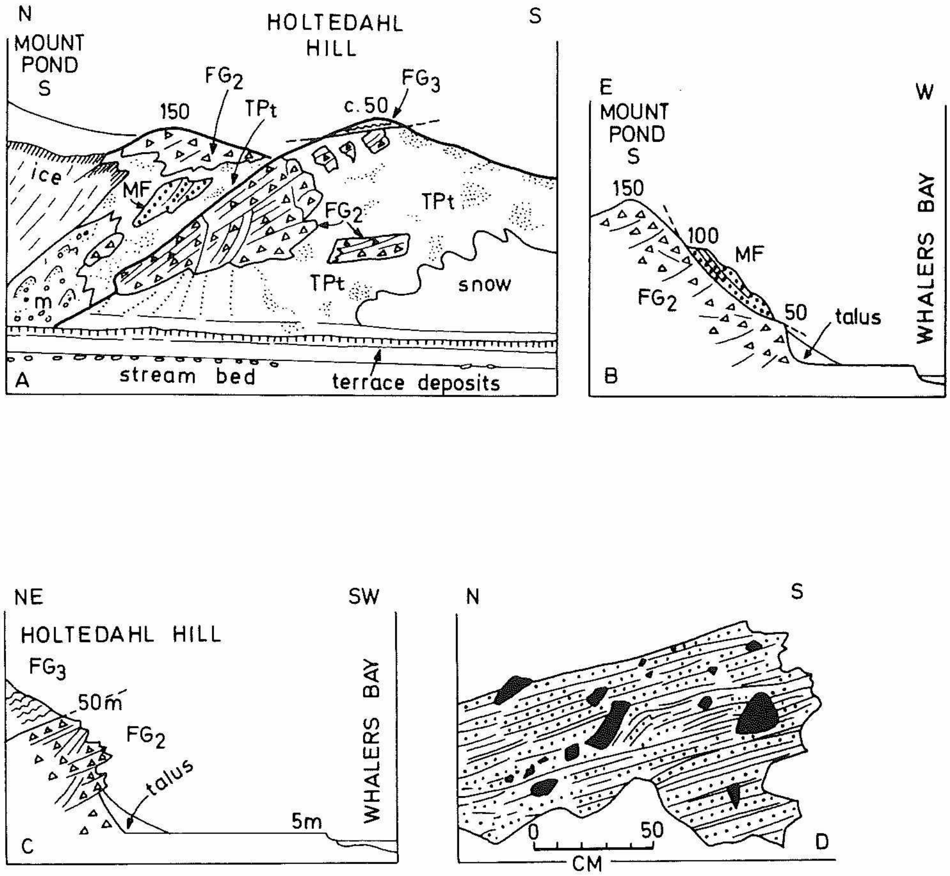

Fig. 10 Exposures of the Foster Group and younger volcanic complexes at Whalers Bay: A – panorama; B, C – cross-sections; D – detail of agglomerate (larger clasts in black). *FG2* – Cathedral Fm. (agglomerate); *FG3* – Stonethrow Fm. (basaltic lavas); *MF* – Murature Fm. (lapilli tuffs); *TPt* – Telefon Fm., Pond phase (tuffs); *m* – moraine

(v) Between Vapour Col and Kendall Point (Figs 3, 26A, B), high coastal cliffs of the island are built of yellow agglomerates of the Cathedral Fm., overlain by lavas and pyroclastics of the Stonethrow Fm., locally also by cemented lapilli tuffs of the Murature Fm. All these units are capped between Mte Irízar and Vapour Col (or Stonethrow Ridge) by tuffs of the Collins Fm. (CF2), and between Telefon Pass and Kendall Point – by tuffs of the Chacao Fm. (ChF).

Close to the shore, immediately south of Kendall Point (at the western entrance to Telefon Pass), there is a line (SSW-NNE) of 6 small craters and mounds marked in the Chacao Fm. tuffs; they could correspond to the 1970 eruption phase (Fig. 26B: ?TG);

(vi) Between Kendall Point and Macaroni Point (Fig. 3), the flat Kendall Terrace is built of yellow agglomerates (Cathedral Fm.) well exposed in steep coastal cliffs, capped by tuffs probably belonging to the Chacao Fm. (ChF). Near North Point, between the agglomerates (Cathedral Fm.) and the tuffs (ChF), appear also consolidated greenish lapilli tuffs of the Murature Fm. type. Further eastward, they are capped by loose black lapilli tuffs of the 1970 eruption (TG);

(vii) The northern steep cliffs of Goddard Hill (Western and Eastern Claws) and Macaroni Point (Fig. 3), are formed of yellow agglomerates of the Cathedral Fm., locally overlain by lava flows and pyroclastics of the Stonethrow Fm. Both formations are faulted. On top of the cliffs, loose black lapilli tuff of the 1970 eruption (TG) was still visible in 1988;

(viii) At Irízar Crater, along its eastern and southern walls (Figs 14A, C, 15), crop out well exposed large-scale cross-bedded yellow-weathered agglomerates of the Cathedral Fm., capped by basaltic lavas of the Stonethrow Fm. and cut by three small dykes (Window Fm.). They are followed by a suite of younger formations: Murature Fm., Collins Fm. and Casco Fm. (see site descriptions under particular formations);

(ix) At Twin Crater (Figs 3, 4), in its south-west corner, crop out large-scale cross-bedded yellow-weathered agglomerates of the Cathedral Fm., with a thin intercalation of reddish scoriaceous lava in the lower part of the exposure, near a small basic dyke (Window Fm.) which cuts through the agglomerates. The agglomerates yielded numerous xenoliths (at this outcrop, and from poorer slope exposure between Twin Crater and Jade Crater Lake), 1-50 cm in diameter: gabbro (several types), amygdaloidal basalt, green basaltic rock, light volcanic rock (rhyodacite-type). Above the agglomerates crop out red-weathered basaltic lavas of the Stonethrow Fm., and still higher, on the slope of Mt Kirkwood, runs the 1842 fissure up to 10 m thick, filled with red basaltic scoria.

Agglomerates of the Cathedral Fm. (with xenoliths of gabbro up to 50 cm in diameter) crop out also in the north-western corner of the crater. They are followed by lavas of the Stonethrow Fm. and capped by loose lapilli tuffs of the Casco Fm.

Thickness: At Cathedral Crags, the thickness of the formation exceeds 150 m; it grows to about 200 m at Mte Irízar and to 250 m or so near South Point; elsewhere, it decreases to about 100 m.

Distribution: The best exposures of the Cathedral Formation are along the east coast of Whalers Bay and at Cathedral Crags (Figs 5–7, 8B, 9B, 10A-D), at Låvebrua Island south of Neptunes Bellows (Figs 3, 8A, 11C), Baily Head (Fig. 9A), at Pendulum Cove between Crimson Hill and Red Spur (Figs 11A, 12), at Stonethrow Ridge (Fig. 13) and at Monte Irízar (Figs 14, 15). Good but rather inaccessible exposures are at New Rock and in steep coastal cliffs between Vapour Col and Kendall Point and further east as far as Macaroni Point (Figs 3, 26A-C).

Remarks:

(i) Holtedahl (1929, p. 31) calculated the thickness of his "yellow tuff" (= agglomerates of the Cathedral Fm. – see my remarks under the heading Foster Group, above) at about 200 m at Mte Irízar and at 135 m at Cathedral Crags which is a very good estimate;

(ii) Hawkes (1961) considered the Cathedral Crags agglomerate to be vent agglomerate;

(iii) González-Ferrán and Katsui (1970, fig. 23) included the tuffs and agglomerates of NE Whalers Bay, Cathedral Crags, Baily Head (Punta Este), Entrance Point and Låvebrua Islet to the pre-caldera parasitic cones (*conos parasitos de Neptuno*), developed on the SE slope of the Foster volcano (*op. cit.* fig. 24A);

(iv) Baker *et al.* (1975, fig. 2) included the Cathedral Crags agglomerates (= Cathedral Fm.) to the "syn-caldera pumiceous tuffs and agglomerates (pyroclast flows)". Other exposures of the Cathedral Fm. (Baily Head, South Point, Låvebrua Islet, NE slope of Mte Galíndez), coastal cliffs between Vapour Col and Macaroni Point, were included by them to the "pre-caldera pyroclasts and lava flows", and to the "early post-caldera lavas and pyroclasts";

(v) Shultz (1970) reported from Cathedral Crags the occurrence of massive, yellow lapilli breccia showing indistinct, nearly horizontal stratification (this is at variance with the present author's recognition of large-scale cross-bedding – see Figs 6, 7). He considered the material as either an ash-flow deposit or a result of Krakatoan-type massive eruptions;

(vi) Smellie (1988, fig.1; 1989, fig. 21.1 & loc. 1, 2) included agglomerates of the Cathedral Fm. to the post-caldera "early tuff cone deposits";

(vii) To the Cathedral Fm. belongs the "yellow tuff formation" (lower and upper members) of Martí and Baraldo (1990, fig. 4: lm + um), attributed by them at Mte Irízar to the pre-caldera deposits, and at Cathedral Crags to the post-caldera deposits (*op. cit.*, Fig. 2). They accept *(op. cit.*, p. 350) the *subaerial character of the YTF* (= yellow tuff formation) *deposits*.

Stonethrow Formation (FG3)

(new unit)

Name: After Stonethrow Ridge, Fumarole Bay (Figs 3, 4, 13). Name introduced by Birkenmajer (1991a, b).

Petrography and structure: The formation consists of grey to black to red massive to scoriaceous and ropy basaltic andesite and basalt lavas forming flows up to 40-50 m thick, alternating with red volcanic breccias (with bombs) and yellow-weathered, often large-scale cross-bedded agglomerates of smaller thickness. The unit interfingers downward with the Cathedral Formation.

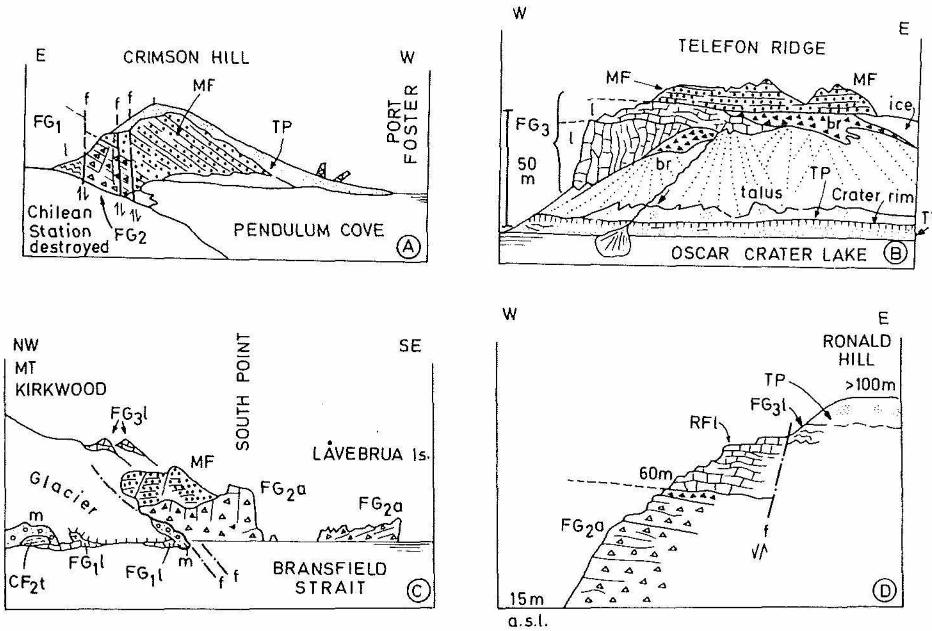

Fig. 11 Exposures of the Foster Group and younger volcanic complexes at various sites inside (A, B, D) and outside (C) the caldera. *FG1* – Entrance Fm. (*l* – lavas); *FG2* – Cathedral Fm. (*a* – agglomerates); *FG3* – Stonethrow Fm. (*l* – lavas; *br* – volcanic breccia); *MF* – Murature Fm. (lapilli tuffs); *RF* – Ronald Fm. (*l* – lava); *CF2* – Collins Fm. (*t* – tuffs); *TY* – Telefon Fm., Yelcho phase (tephra); *TP* – Telefon Fm., Pond phase (tuff and bombs); *f* – faults

Selected site description:

(i) At Stonethrow Ridge (Figs 13, 26A, B), there are very instructive sections of alternating lavas and pyroclastics, dislocated by ring and radial faults. Consolidated lapilli tuffs of the Murature Fm. occur at some places, being also involved in the same faulting pattern;

(ii) At Telefon Ridge, above larger of the two Oscar Lakes (Fig. 11B), crops out grey, columnar basaltic lava flow 40-50 m thick, inclined at 20° due SW. It is overlain by platy-jointed grey basaltic lava flow, and that by deep-red volcanic breccia consisting of red scoria and bombs (Stonethrow Fm.). Horizontally stratified, grey consolidated lapilli tuffs (Murature Fm.) rest unconformably upon the platy lava and the breccia. Downslope, above the lake, there is another exposure of similar volcanic breccia (Stonethrow Fm.) probably downthrown by a ring fault;

(iii) At Red Crag and South East Point (Fig. 9B), there are grey to black lava flows, scoriaceous in the top part, with vivid-red scoria and flow breccia at the base; twisted bombs up to 30 cm large occur there. There are also black to grey basaltic veins cutting through agglomerates of the Cathedral Fm. just below the lavas (feeder veins ?);

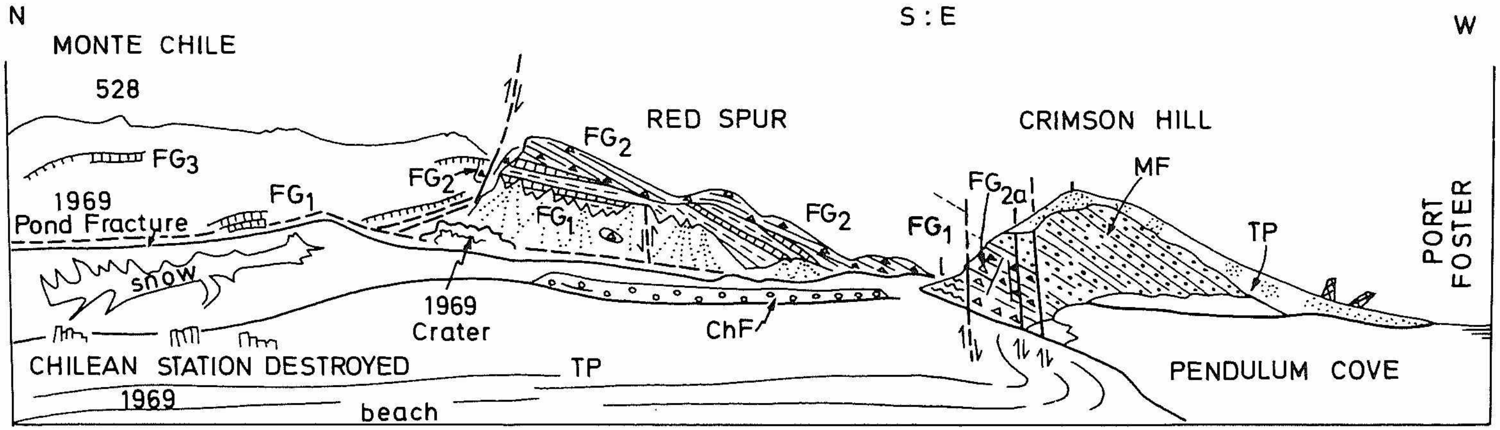

Fig. 12 Geological panorama at Pendulum Cove. Explanations – as in Fig. 11

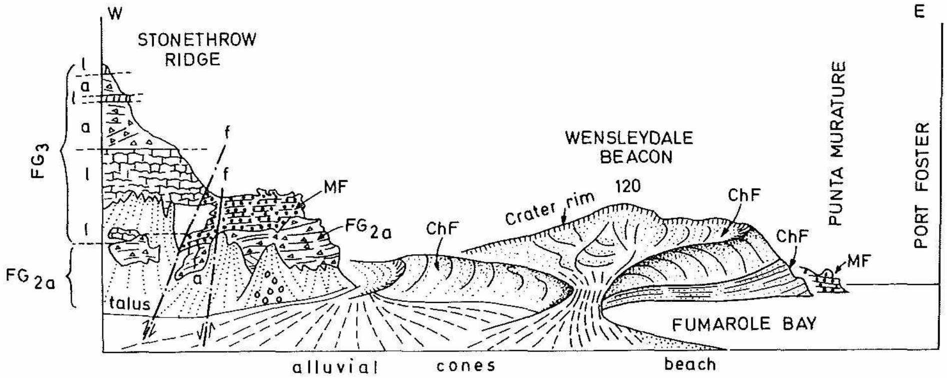

Fig. 13 Geological structure between Stonethrow Ridge and Punta Murature. *FG2* – Cathedral Fm. (*a* – agglomerate); *FG3* – Stonethrow Fm. (*a* – agglomerate; *l* – lava); *MF* – Murature Fm. (lapilli tuffs); *ChF* – Chacao Fm. (tuffs); *f* – faults

(iv) At Ronald Hill (Figs 11D, 16), the basaltic lavas (Stonethrow Fm.) overlying yellow agglomerates (Cathedral Fm.) are ropy and agglomeratic, with lava cakes and bombs 5-30 cm in size;

(v) At Punta Buen Tiempo, in front of Black Glacier (Fig.3), occur poorly exposed red lavas which may belong to the Stonethrow Fm.

Thickness: The thickness of the formation at Stonethrow Ridge is 150-200 m; elsewhere it is closer to the lower value.

Distribution: The best exposures of the Stonethrow Formation are at Stonethrow Ridge (Fig. 13), Holtedahl Hill, Whalers Bay (Figs 10A, C), Red Crag, Cathedral Crags (Fig. 9B), Telefon Ridge (Fig. 11B), and at Monte Irízar (Figs 14, 15).

Remarks:

(i) Hawkes (1961, figs 4, 5 & geol. map) included the Stonethrow Ridge sequence (Fumarole Bay volcanics) and the Telefon Ridge sequence (Telefon Bay volcanics) to the Port Foster Group (pre-caldera). González-Ferrán & Katsui (1970, Fig. 23) followed him;

(ii) The exposure at Macaroni Point illustrated by Baker *et al.* (1975, fig. 5) shows lava flows alternating with red scoria (equivalent to the Stonethrow Fm.) and overlain by yellow tuff. According to the present author's observations from the ship, there is a vertical fault between the lava unit and the "yellow tuff" (agglomerate of the Cathedral Fm.) downthrowing the lavas;

(iii) Smellie (1988, fig. 1; 1989, fig. 21.1 & loc. 1, 2) includes the lavas and tuffs here attributed to the Stonethrow Fm. – to the "post-caldera deposits";

Window Formation (FG_4)

(new unit)

Name: After Neptune Window in Cathedral Crags, Whalers Bay (Fig. 6). Name introduced by Birkenmajer (1991a, b).

Petrography and structure: The unit consists of thin trachybasalt (and basaltic-andesite according to some authors – see Remarks, below) dykes usually cutting through the Cathedral Formation agglomerates (Figs 6, 7, 14, 15), sometimes also through the Entrance Formation and the Stonethrow Formation. These dykes may have intruded at initial stage of ring faulting which led to the Deception caldera collapse.

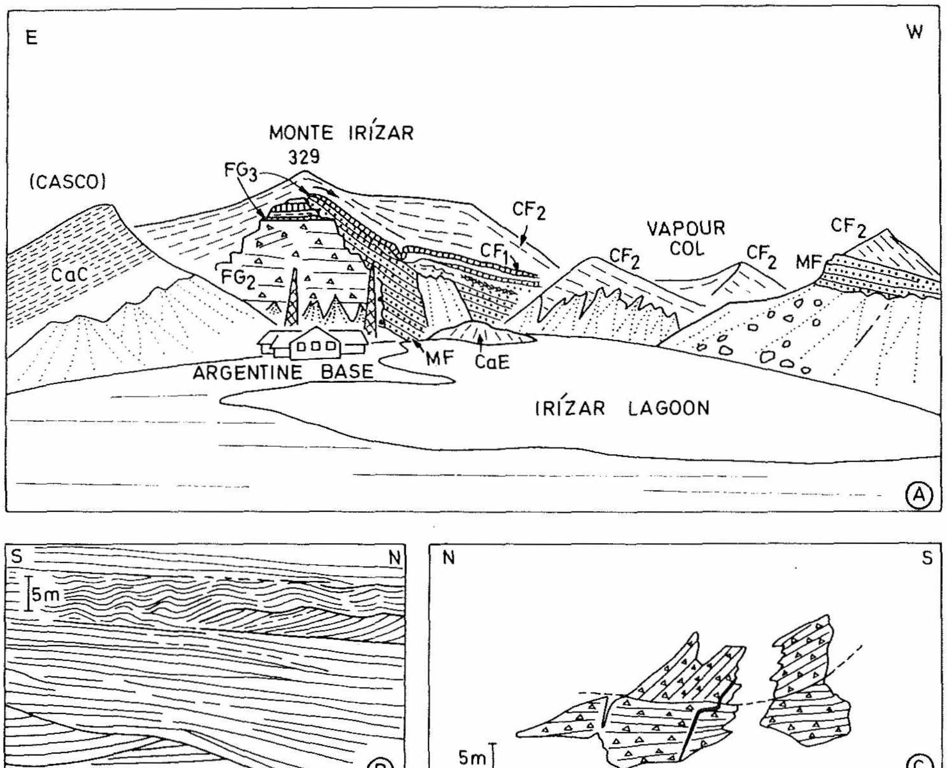

Fig. 14 A. Geological panorama of Monte Irízar and its vicinity. *FG2* – Cathedral Fm. (agglomerates); *FG3* – Stonethrow Fm. (basaltic lavas and tuffs, subordinately agglomerates); *MF* – Murature Fm. (lapilli tuffs); *CF* – Collins Fm. (*CF1* – trachydacite lavas and pyroclasts; *CF2* – tuffs); *CaC* – Casco Fm., Casco phase (tuffs); *CaE* – Casco Fm., Emerald phase (tuff cone with crater).
B. Detail of large-scale cross-bedding (dune-bedding, partly in-phase) in the upper part of the Murature Fm. at Monte Irízar.
C. Detail showing relation of basaltic (trachybasalt ?) dyke (Window Fm.) to large-scale cross-bedded agglomerate of the Cathedral Fm. below Casco hill, at Irízar Crater (see Fig. 15). A-C – after Birkenmajer (1991b)

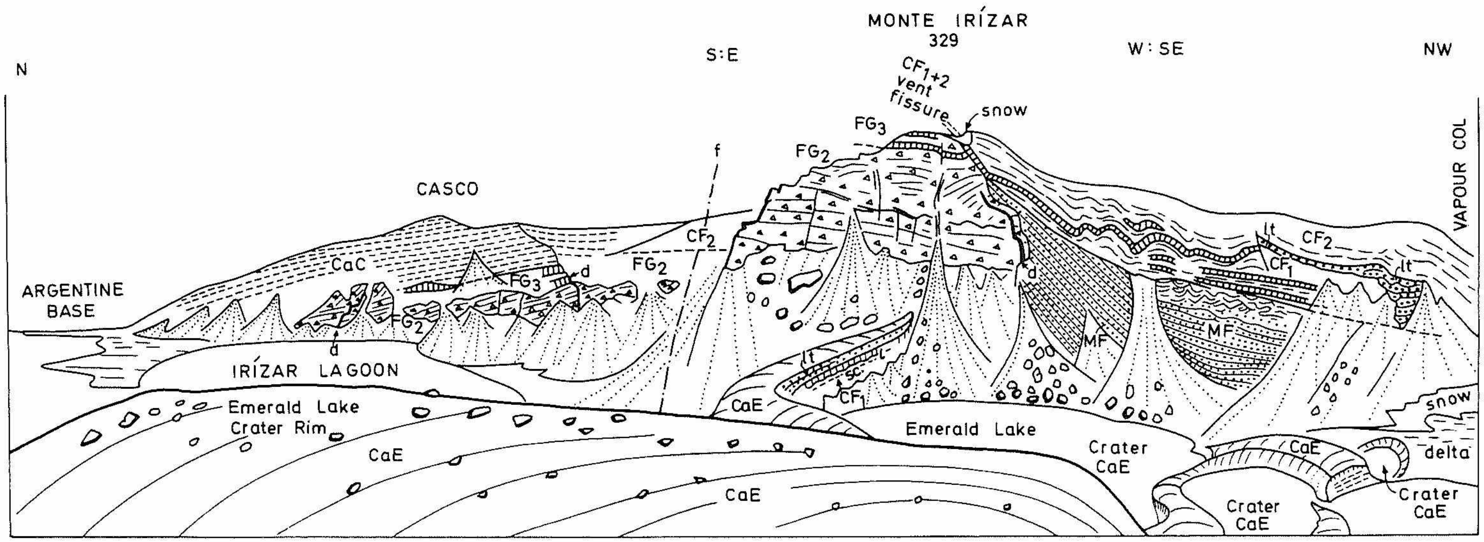

Fig. 15 Geological structure of Monte Irízar and its vicinity. Explanations of symbols – as in Fig. 14A-C; *lt* – lithified tuff. After Birkenmajer (1991b)

Selected site description:

(i) At Cathedral Crags, there occurs a trachybasalt dyke 10-15 cm thick only, cutting through agglomerates of the Cathedral Fm. (Figs 6, 7). The exposure is at 45-50 m a.s.l., about 150 m west of Neptunes Window. The dyke rock is vesicular, with empty vesicles;

(ii) At Irízar Crater, there occur three dykes: two at the eastern side of the crater below Casco Cone (Fig. 15), and one at the western side of the southern wall of the crater (Mte Irízar – Fig. 15). The first dyke, closest to Argentine Base (Fig. 15; 14C), is 0.5 m thick and represented by grey massive basaltic rock; it cuts through large-scale cross-bedded agglomerates (Cathedral Fm.), at first subvertically, at high angle to the bedding of the agglomerate, then stepwise, accomodating to cross-bedding of a higher set and becoming an upward wedging-out sill. The second dyke, further south, is 1.2 m thick, consisting of grey, massive to vesicular basaltic rock; it cuts through the Cathedral Fm. agglomerate and through a lower part of basaltic lavas of the overlying Stonethrow Fm. The third dyke (westernmost) is about 2 m thick in the lower part, wedging-out upwards, represented by grey massive basaltic rock; it cuts entirely through large-scale cross-bedded agglomerates of the Cathedral Fm.;

(iii) At Twin Crater (Figs 3, 4), in its south-west corner, a grey basic dyke 0.5 m thick (Window Fm.) cuts through the Cathedral Fm. agglomerates in the lower part of the exposure.

Remarks:

(i) These dykes were known already to Holtedahl (1929, p. 32) from the vicinity of Mte Irízar, and to Olsacher (1956, p. 27, 28) from the area between Argentine Base and Telefon Ridge;

(ii) Hawkes (1961, p. 16, fig. 7) reported the occurrence of an olivine basalt sill 1 ft thick at "Vapour Col vent" (= Mte Irízar) between "massive agglomerate" 200 ft thick (= Cathedral Fm.) and "whitened agglomerate" 3 ft thick (= Cathedral Fm.), which was followed by "stratified tuffs and agglomerates with lava flows near the top, 150 ft" (= Cathedral Fm. & Stonethrow Fm. – see Fig. 15). Hawkes' sill is probably a prolongation of the dyke which cuts through the Cathedral Fm. agglomerates above Emerald Lake (Fig. 15);

(iii) Shultz (1970) recognized basalt dykes 0.3 to 1 m thick cutting through "vent complex" north of Argentine Station (= at Stonethrow Ridge). Faure *et al.* (1971) analysed a sample from "basaltic andesite dyke intruding Fumarole Bay vent" (same locality as Shultz, 1970).

(iv) Baker *et al.* (1975, fig. 4) marked two subvertical dykes (= Window Fm.) subparallel to faults which cut through lavas and red scoria (= Entrance Fm.) at Entrance Point.

HAWKES GROUP (HG)

(new unit)

Name: After Hawkes Glacier, a large glacier which covers the eastern part of Deception Island ending in almost linear, NNW-SSE-running, probably fault-controlled ice-cliff at Bransfield Strait (Figs 3, 4). Name introduced by Birkenmajer (1991a, b).

Subdivision: The Group includes 7 formations of the syn- to post-caldera assemblage: the Murature Fm.; the Ronald Fm.; the Collins Fm.; the Chacao Fm.; the Casco Fm.; the Kirkwood Fm.; and the Telefon Fm. (Tab. 1).

Petrography and form: The Hawkes Group is characterized by very variable petrography, in the succession: (1) from andesite tephra (Murature Fm.) through trachydacite plug, lava and tephra (Ronald and Collins fms), (2) and from basaltic andesite tephra (Chacao and Casco fms) through basalt lava and tephra (Kirkwood Fm.) to andesite tephra, subordinately lava (Telefon Fm.) – Tabs 1, 2. The Murature Formation (syn-caldera) is involved in radial and ring faulting related to the caldera collapse (Fig 3; Fig. 12: Crimson Hill; Fig. 13: Stonethrow Ridge). The succeeding formations (post-caldera association – Tab. 1) rarely show the presence of faults related to the caldera collapse pattern.

Structure and age: The age of the Hawkes Group is Late Quaternary, probably entirely Holocene. The volcanic activity which produced the youngest two formations is historically documented: Telefon Fm. – 1967-1970; Kirkwood Fm. – KK: 1842, KR – prior to 1912. The remaining five formations are pre-1929 in age.

The Casco, Chacao and Collins fms are most probably also Late Holocene, as is indicated by the degree of preservation of their cones and craters, in decreasing order: very fresh in case of the Casco Fm.; somewhat modified or even considerably destroyed by later eruptions (and silted) in case of the Chacao Fm.; stronger modified by erosion and subsequent eruptive activity in case of the Collins Fm.

The Ronald Fm. may be as old as or slightly older than the Casco Fm., however the original central volcano of Ronald Hill had been strongly modified by younger explosive activity.

Finally, the Murature Fm. cones are preserved fragmentarily. They are often incorporated in younger volcanic structures, faulted and displaced, and never show a complete cone or crater structure. The age of the formation may thus be either Middle or Early Holocene or even Late Pleistocene.

Remarks: The eruptive centres which are responsible for tephra and lava of particular formations of the Hawkes Group formed mainly as a response to intermittent caldera subsidence along ring and radial faults (Murature through Kirkwood fms), partly also as a result of interplay of caldera subsidence and a NNW-SSE-directed strike-slip displacement parallel to the Hero Fracture Zone. All syn-caldera and post-caldera eruptive centres of the Hawkes Group are located inside the Deception caldera rim (Fig 3). The tension gash system of the Pond phase eruption (Telefon Fm.) runs through the inner slopes and highest crest of Mount Pond (548 m) along the eastern rim of the caldera.

Murature Formation (MF)

(new unit)

Name: After Punta Murature, western part of Port Foster (Figs 3, 4). Name introduced by Birkenmajer (1991a, b).

Petrography and structure: The formation represents products of phreatic eruptions, predominantly well-cemented green lapilli tuffs. Structurally, the formation seems to be directly related to the caldera collapse along ring faults, thus syn-caldera in age (Tab. 1). It is also probable that flooding of the caldera by the sea through a breach at Neptune Bellows had occurred already at this stage. The Murature Formation is vertically displaced by both ring and radial faults, as is also the case with the Foster Group.

Selected site description:

(i) At Punta Murature (Fig. 19C), within volcanic cone of feebly cemented tephra of the Chacao Fm. (Wensleydale Beacon cone), crop out strongly cemented, dislocated blocks of the Murature Fm. forming picturesque crags. This is a hard, green, well stratified lapilli tuff, with alternating bands of coarser (1–2 cm) and finer (0.5–1 cm) lapilli. Within the lapilli bands, there occur also numerous black vesicular volcanic bombs 2–25 cm in size, and fragments of older rocks: red scoria and grey basaltic lava (from the Foster Gp), and yellow agglomerate (Cathedral Fm. type). (N.B., cold, non-hydrosulfuric gas bubbles appear at the beach at low tide);

(ii) At Fumarole Bay, northern side of Stonethrow Ridge facing Wensleydale Beacon, crop out green, well cemented, horizontally stratified lapilli tuffs of the Murature Fm. They rest directly upon yellow agglomerates of the Cathedral Fm. and are faulted together with them (Fig. 13). The Murature Fm. is separated by a ring fault from red scoriaceous lavas alternating with agglomerates (Stonethrow Fm.). (N.B. Numerous whalebones partly covered by alluvial fan are scattered on the beach at 2-3 m above sea level. In 1988, there was a strong hot hydrosulfuric fumarole activity, boiling at low tide in the bay);

(iii) At the western shore of Lago Irízar, near the entrance to the lagoon (Fig. 3), crop out well cemented green lapilli tuffs with frequent coarser bands (Murature Fm.), dipping 15–20° due south. Fragments of older rocks occur in the tuffs: yellow agglomerate (Cathedral Fm. type), red scoriaceous and grey massive lavas (Foster Gp);

(iv) At the western slope of Mte Irízar (Figs 14A, B, 15), the Murature Fm. is represented by greenish-grey, well stratified and cemented lapilli tuff, consisting of subrounded lapilli 1–5 cm in diameter, alternating with fine-grained tuff. The rocks dip at 30° due NW. Wind-formed dunes, partly in-phase, occur in a higher part of the formation, in a zone about 5 m thick;

(v) At Crimson Hill (Figs 13, 11A, 12), the Murature Fm. is represented by grey to green and grey-yellowish stratified lapilli tuff agglomerate dipping at 30° due north-west, displaced (together with the Foster Group rocks) stepwise towards Port Foster;

(vi) At Ronald Hill (Fig. 16), the Murature Fm. consists of grey to greenish stratified cemented lapilli tuff, with blocks of yellow agglomerate (from Cathedral Fm.) in its lower part. The formation underlies trachydacite lava of the Ronald Fm.;

(vii) On top of Cathedral Crags (Figs 3, 5), upon the Cathedral Fm. agglomerate rests the Murature Fm. consisting of green-grey stratified lapilli tuff with numerous clasts of black glassy lava, grey basaltic lava, greenish weathered tuff, yellow palagonitic clay, and scarce dark-green gabbroic rock. The Murature Fm. dips due N and NW at 15-20° and is juxtaposed by a NE-SW-running fault against agglomerates of the Cathedral Fm. of the northern part of the exposure;

(viii) At Red Crag (Fig. 9B), the Murature Fm., similar in character to that exposed at Cathedral Crags (vii), rests directly upon basaltic-andesite lava of the Stonethrow Fm., and is down-faulted together with the lava against agglomerate of the Cathedral Fm.;

(ix) At South Point (Fig. 11C), green, consolidated and stratified lapilli tuffs of the Murature Fm. rest directly upon yellow agglomerates of the Cathedral Fm., being faulted with the latter.

Distribution: The formation is spread all over the island, particularly along inner ring faults of the Port Foster lagoon (Fig. 3): at Whalers Bay-Cathedral Crags; Pendulum Cove; Sealers Harbour; Telefon Ridge; Stonethrow Ridge; and Monte Irízar (Figs 5, 9B, 10A, B, 11A, B, D, 12, 13-16, 19), but also as patches along the outer circumference of Deception Island (Figs 11C, 26A, B).

Remarks:

(i) To the Murature Fm. belong tuffs attributed by Hawkes (1961: geol. map) to the Pendulum Cove Gp (post-caldera): at Punta Murature (Wensleydale Beacon), at Cathedral Crags, at Holtedahl Hill NE of Whalers Bay, and near Vapour Point, but not elsewhere;

(ii) To the Murature Fm. belongs a considerable part of andesitic lapilli tuff (pre-caldera) of González-Ferrán & Katsui (1970, fig. 23): east and north-east of Whalers Bay, southern part of Mte Galíndez, near Vapour Point, at Telefon Ridge and near North Point;

(iii) The description of the *grey and khaki-colored, planar and rarely cross-stratified lapilli tuffs* at the eastern side of Wensleydale Beacon (= Punta Murature) by Smellie (1989, p. 148: loc. 3) refers to the Murature Fm. To this formation belong also Smellie's (*op. cit.*, p. 152, loc. 8) *deposits from multiple surges (western outcrop)* at the Irízar Crater section (*cf.* Fig. 14, 15: MF);

(iv) To the Murature Fm. belongs a lower part of the "post-caldera base surge and strombolian deposits"of Martí & Baraldo (1990, fig. 4: P) which unconformably contact at high-angle (*op. cit.*, Fig. 5) with nearly flat-lying agglomerates of the Cathedral Fm. (see Figs 15, 16).

Ronald Formation (RF)

(new unit)

Name: After Ronald Hill, west of Whalers Bay (Figs 3, 4, 11D, 16). Name introduced by Birkenmajer (1991a, b).

Petrography and structure: The formation consists of trachydacite lava flow and trachydacite plug (feeder), the remains of considerably destroyed small parasitic central volcano located on the inside of the Deception caldera. A single occurrence of this formation is at Ronald Hill (about 100 m high). There, the plug and related lava post-date yellow agglomerates of the Cathedral Fm., red to black basaltic lavas of the Stonethrow Fm., and green lapilli tuffs of the Murature Formation, but pre-date the ejecta and maar forms of the Kendall Crater (Chacao Fm.) and the Airstrip Crater (Casco Fm.), and loose tuffs of the Telefon Fm. (Figs 3, 16).

Site description:

At Ronald Hill, the trachydacite lava flow is bluish-grey, locally with pinkish to brownish hue, massive or vesicular (near the top of of the flow), platy jointed. The plug consisting of the same trachydacite shows a system of fanwise joints (Fig. 16).

Distribution: The formation occurs only at Ronald Hill (Figs 3, 11D, 16). It may correlate in age, and certainly in trachydacitic character of the lava, with the Collins Formation.

Remarks:

(i) Holtedahl (1929, figs 14, 15) was the first to describe lavas of the Ronald Fm. as superimposed on "yellow tuffs" (= Cathedral Fm.);

(ii) Hawkes (1961) included the Ronald Fm. rocks (together with agglomerates and lavas of the Foster Group *sensu mihi)* to the Pendulum Cove Gp;

(iii) González-Ferrán & Katsui (1970, fig. 23) included the rocks at Ronald Hill to the post-caldera series;

(iv) Faure *et al.* (1971) reported on the occurrence at Ronald Hill of slightly porphyritic oligoclase trachyte flow (= Ronald Fm.);

(v) Smellie (1988, 1989) attributed the rocks of the Ronald Fm. to the "post-caldera deposits".

Collins Formation (CF)

(new unit)

Name: After Collins Point, west of Neptunes Bellows (Figs 3, 4). Name introduced by Birkenmajer (1991a, b).

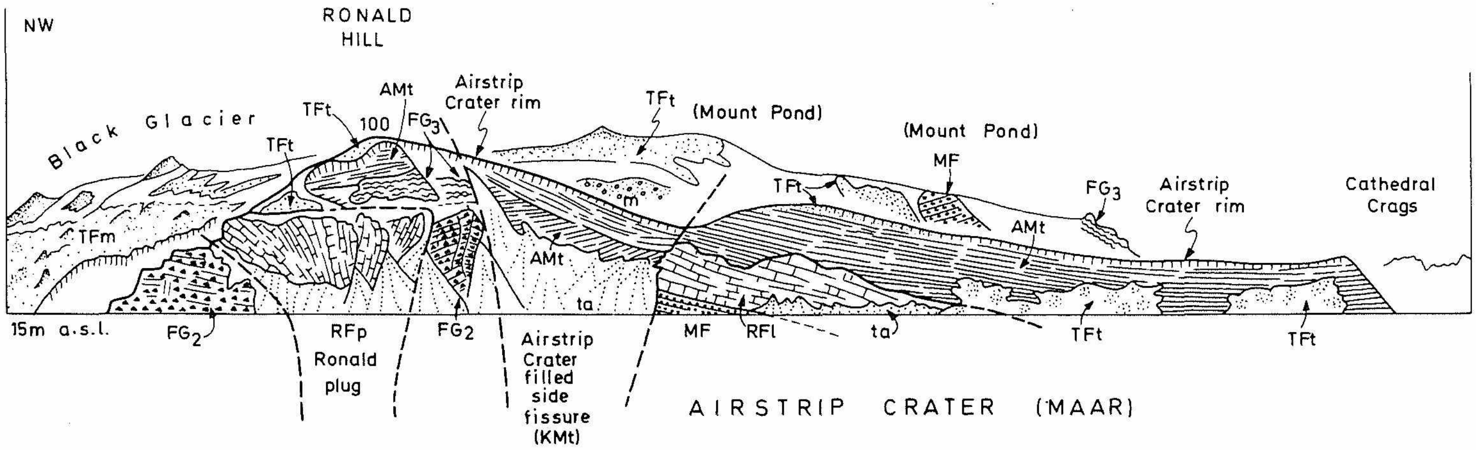

Fig. 16 Geological structure of Ronald Hill. *FG2* – Cathedral Fm. (agglomerate); *FG3* – Stonethrow Fm. (basaltic lavas); *MF* – Murature Fm. (lapilli tuffs); *RF* – Ronald Fm. (*RFp* – trachydacite plug; *RFl* – trachydacite lava); *AMt* – Airstrip Maar, tuff (Casco Fm.); *TFt* – Telefon Fm., Pond phase (tuff); *ta* – talus; *m* – moraine. After Birkenmajer (1991b)

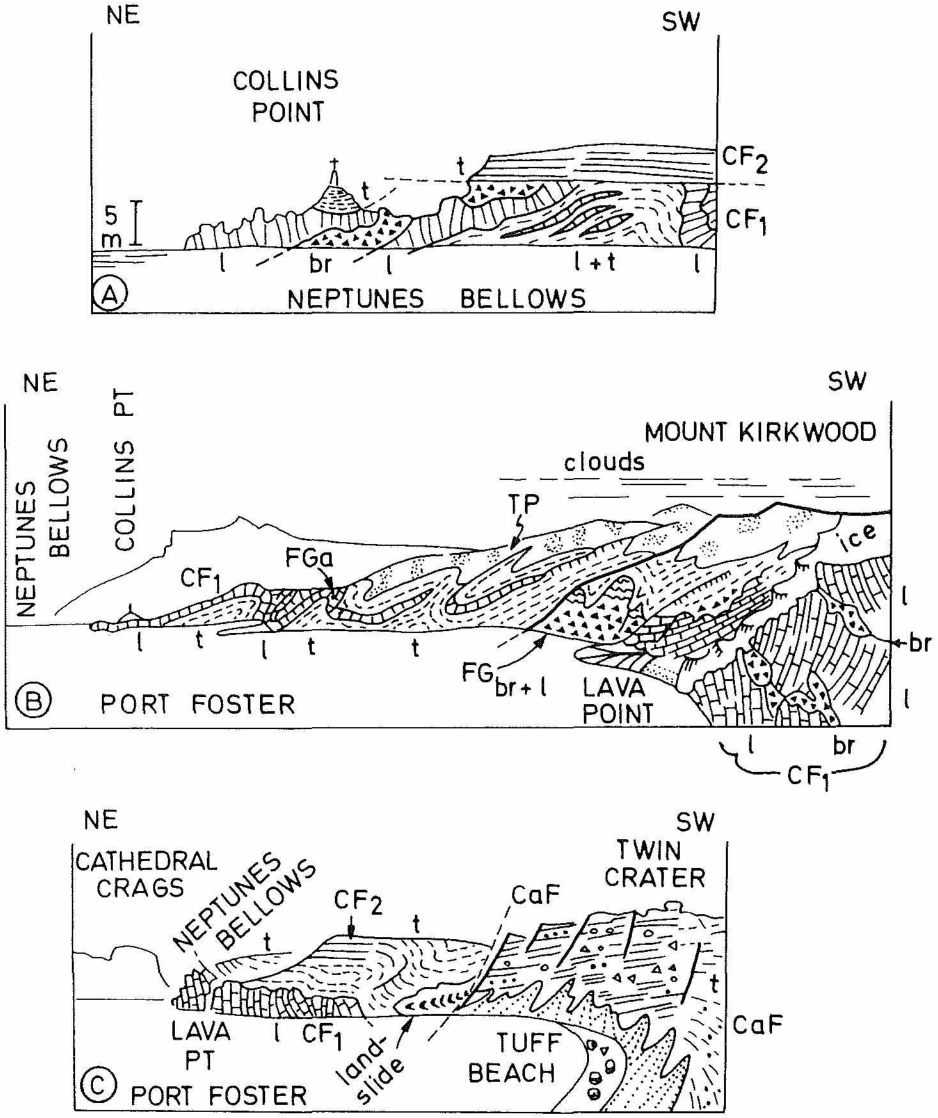

Fig. 17 A-C. Geological panoramas from Collins Point to Twin Crater. *FG* – Foster Gp; *CF* – Collins Fm. (*CF1* – trachydacite lavas and tuffs; *CF2* – tuff cover); *CaF* – Casco Fm.; *TP* – Telefon Fm., Pond phase (tuffs); *a* – lava-agglomerate; *br* – volcanic breccia; *t* – tuff. After Birkenmajer (1991b)

Petrography and structure: The Collins Formation consists of several thin, usually light-grey, seldom reddish, trachydacite lava flows 1–5 m thick, alternating with scoriaceous lava breccias and tuffs in the lower part (CF_1: about 10 m thick), capped by tuff (CF_2: a minimum 25 m thick) – Figs 17, 18, 14, 15. The tuff-filled craters attributed to the Collins Formation are rela-

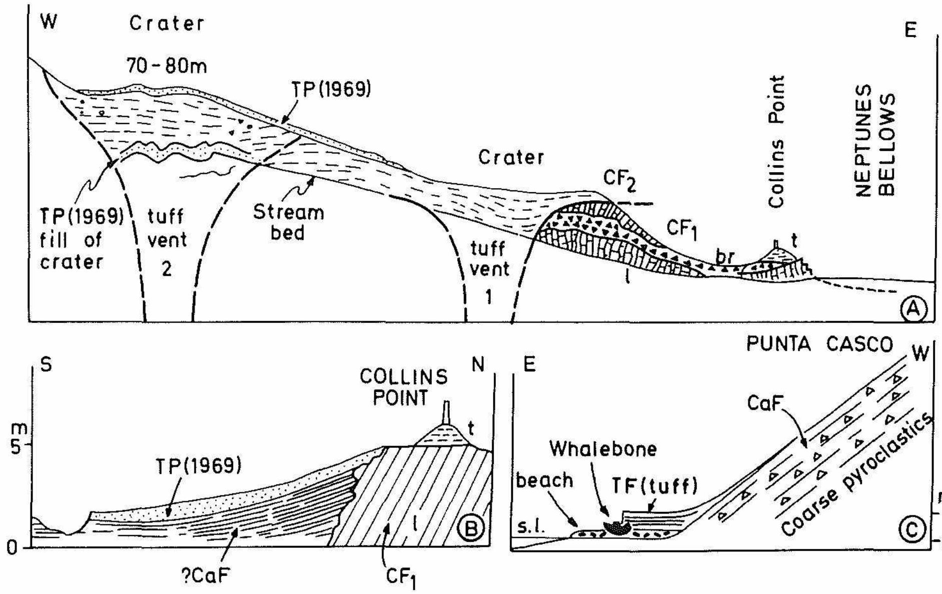

Fig. 18 Geological relations at Collins Point (A, B) and Punta Casco (C). *CF1* – Collins Fm. (*l* – lava; *br* – volcanic breccia; *t* – tuff); *CF2* – Collins Fm. (tephra); *CaF* – Casco Fm. (tuffs); *TP* – Telefon Fm., Pond phase (tuff)

tively well preserved, and only partly filled with still younger volcanic products and/or solifluction (Figs 19A, B).

Selected site description:

(i) At Collins Point (Figs 17A, 18A), there occur several trachydacite lava flows 1-3 m thick, grey to brownish-grey if fresh, to reddish-brown if weathered, alternating with lava breccia and tuff. The lava flows are scoriaceous at the top, massive in the middle, with basal flow breccias at the bottom (CF_1). The tuffs (CF_2) which unconformably cover the lavas contain, i.a., lava fragments from the underlying flows, as well as clasts of yellow agglomerate (Cathedral Fm.) and red scoria (Foster Gp);

(ii) Above Collins Point (Figs. 3, 18A), there occur two vents filled with semi-consolidated grey-green lapilli tuff attributed to the Collins Fm. (CF_2). They contain numerous fragments of grey lava of the Collins Fm. type (CF_1). Unconformable contact of the tuffs (CF_2) with the lava flows and lava-breccias (CF_1) is well visible at Point Collins;

(iii) At Lava Point (Figs 17B, C), occur several rather irregular lava flows 1-5 m thick of columnar, grey (reddish at the surface) aphanitic to slightly porphyritic trachydacite, separated by thin, irregular lava breccias containing volcanic bombs. The lava complex (CF_1) is about 10 m thick. It is locally overlain by black to brown-red and yellowish-red very porous scoriaceous lava, followed by stratified semi-consolidated lapilli tuff passing to bomb-breccia, 15–25 m thick (CF_2). A block of the Foster Group rocks (Fig. 17B) juts out from the tuffs. It consists of yellow agglomerate (Cathedral Fm.) overlain by vivid-red scoriaceous lava passing to grey-brown basaltic andesite lava (Stonethrow Fm.);

(iv) At Falsa Punta Rancho (Fig. 3), above lavas of the Entrance Fm. rest feebly cemented stratified tuffs with larger blocks, corresponding to the Collins Fm. (CF_2). A crater resembling those of the Collins Fm. above Collins Point (see Fig. 18A) is visible in the tuffs opposite Låvebrua Islet (Fig. 3);

(v) At South Point, South West Point, and as far west as Vapour Col (Figs 3, 11C, 26A, B), there are exposures near sea level of semi-consolidated tuffs resembling those of the Collins Fm. (CF_2). They rest either on red lavas (Entrance Fm.) or yellow agglomerates (Cathedral Fm.), or on consolidated green lapilli tuffs (Murature Fm.);

(vi) At the eastern side of the Emerald Lake crater (Fig. 15), attributed to the Emerald phase (CaE) of the Casco Formation, there is a section of lavas and tuffs attributed to the Collins Formation (from bottom upwards): (1) red scoriaceous lava and volcanic breccia (more than 5 m); (2) grey to reddish scoriaceous lava flow (1–2 m); (3) greenish cemented lapilli tuff (1–1.5 m). The section is covered by loose tuff with blocks at the surface (4) attributed to the Casco Fm., Emerald phase (CaE). The rocks (1)-(3) are very similar to those exposed at the western wall of the Irízar Crater which are also included to the Collins Fm. (Fig. 15);

(vii) At Jade Crater Lake (Figs 3, 22), in the western and northern walls of the crater formed during the Casco phase (CaC), we see light-grey massive trachydacite lava flows, becoming dark-grey and scoriaceous in the upper part, attributed to the Collins Fm. (CF_1). They are capped by loose tuffs of the Casco Fm.

Distribution and age: The Collins Formation occurs along the southern arc of the caldera, between Fumarole Bay and Monte Galíndez, with craters located inside caldera rim (Fig. 3). The cruptions certainly had occurred prior to 1829, as may be inferred from Kendall's map (in Barrow, 1831; see also Fig. 24A) which shows the coastline between Entrance Point and Fumarole Bay as nearly identical with the present one.

Remarks:

(i) Petrographically, both the Collins and Ronald formations are represented by trachydacite, and may represent the same phase of volcanic activity which terminated the first volcanic cycle on Deception Island (Tab. 1);

(ii) Olsacher (1956, fig. 3) attributed the rocks of the present Collins Fm. to "serie volcanica moderna", but incorrectly assumed that the lavas (determined as basalts) intruded into morainic deposits (*op. cit.*, figs 4, 5);

(iii) Hawkes (1961: geol. map) included the lavas of the Collins Fm. at Collins Point and Lava Point to the Pendulum Cove Gp (post-caldera);

(iv) Baker *et al.* (1975, fig. 2) included the Collins Fm. lavas at Collins Point and Lava Point to the "post-caldera lava flows".

Chacao Formation (ChF)

(new unit)

Name: After Chacao Crater (synonym: Cross Hill), Telefon Bay (Figs 3, 4). Name introduced by Birkenmajer (1991a, b).

Petrography and structure: The formation is represented by several comparatively well preserved tephra cones of basaltic andesite character, distributed along the inner ring of the Deception caldera, with preserved craters (Chacao phase - ChC), and by a series of large maars (Kendall phase - ChK) – Fig. 3. The character of the tephra, lithologically very similar to that of the Yelcho Hill (TY phase), suggests phreatic eruption.

Selected site description:

(i) At Punta Chacao, the eastern wall of the Chacao Crater cone (= Cross Hill) is about 25 m high, exposing well-bedded dark-grey to greenish semiconsolidated tephra, mainly fine- to medium-grained lapilli tuff (0.5-1 cm in diameter) with single, larger older lava clasts, and with black scoriaceous bombs (Fig. 19A, B);

(ii) The Wensleydale Beacon cone consists of feebly cemented tephra (mainly lapilli tuffs) similar to that of Chacao cone, subhorizontally stratified in the lower part (Figs 13, 19B). Blocks of strongly cemented green lapilli tuffs of the Murature Fm. jut out of the cone at Punta Murature and at sides of poorly marked crater of the Wensleydale Beacon cone above Wensleydale Valley (Figs 3, 13, 19B). (N.B. The valley is covered with alluvial fans with poorly marked low terraces. Whale bones are scattered in the valley at a distance of up to 50 m from the present - 1988 - high-water mark. Some old logs, apparently from wrecked boats, lie half-buried by alluvial fan. In 1988, the surface of alluvial fan was still covered by a thin black layer of the 1967 and/or 1969 fine lapilli and ash. There were also low-temperature non-hydrosulfuric gas exhalations visible as bubble chains at low tide in the bay);

(iii) At Scalers Point (Figs 3, 20A), the Chacao Fm. consists of grey-green, moderately cemented, stratified lapilli tuff, dipping at low angles due south. Single larger clasts occur in the tuff, consisting of: light-grey to bluish lava (Ronald-Collins fms type), 5–20 cm in size, and yellow agglomerate (Cathedral Fm. type), 30–40 cm in size. The tephra exposure in the Scalers (INACH) Crater is 10–15 m high at Scalers Point, the crater wall rising inland to 40 m a.s.l. Ring faults are visible on the inner size of the crater (Figs 20A, B), stepwise displacing the tephra towards the crater centre. Its floor is silted with black stratified tuff and grey-greenish lapilli tuff of the Telefon Fm.

The previous Scalers Harbour, still open in 1829 (Fig. 24A), is presently completely silted and modified by the explosive activity of the INACH Crater

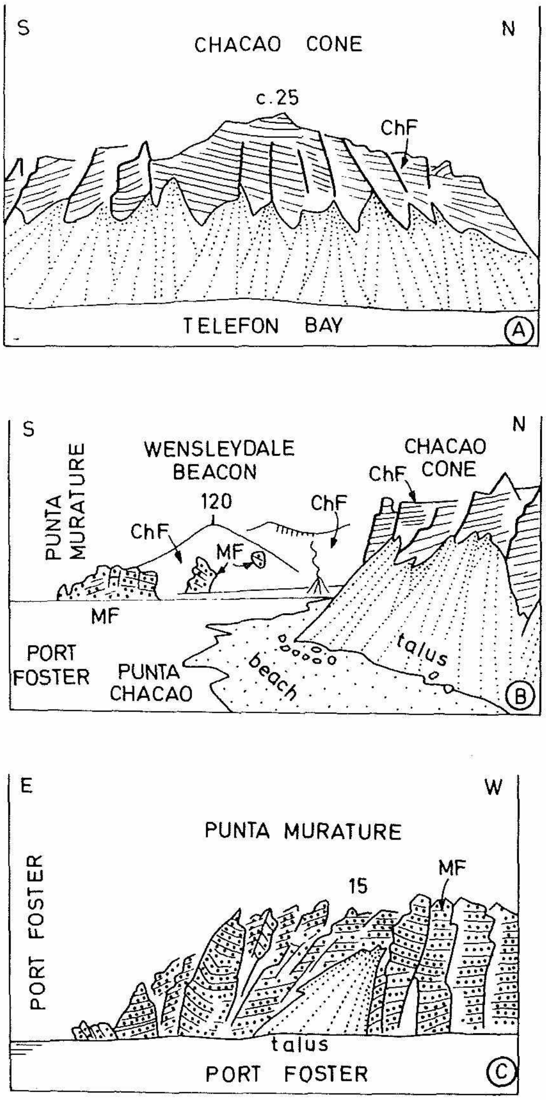

Fig. 19 Volcanic formations between Chacao Cone (A, B) and Punta Murature (B, C). *MF* – Murature Fm. (lapilli tuffs); *ChF* – Chacao Fm. (tephra)

(1969 land eruption centre), and subsequent (mainly 1970) ashfall and slope-wash.

Distribution and age: Volcanic cones with craters (often flooded) opening towards the Port Foster lagoon, here attributed to the Chacao Formation (Chacao phase - ChC), and large maars (Kendall phase - ChK) are recognizable on Kendall's 1829 map (see Barrow, 1831; Roobol, 1973, 1979; Birkenmajer, 1991b) – Fig. 24A. The cones follow the northern arc of ring faults in the Deception Island caldera: Wensleydale Beacon (Figs 13, 19B); Chacao Cone

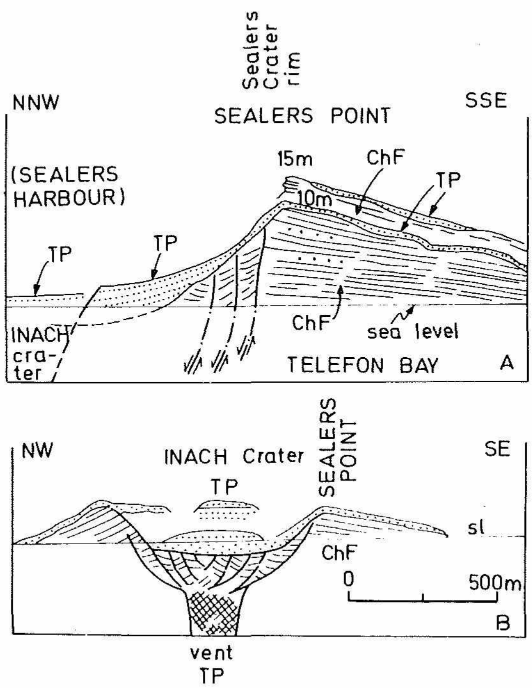

Fig. 20 Structure of the INACH Crater at Sealers Point. *ChF* – Chacao Fm.; *TP* – Telefon Fm. (Pond phase)

with crater (= Cross Hill; silted and considerably modified by the 1967-1970 eruptions – see González-Ferrán, 1971; see also Figs 19A, B, 25); Sealers Harbour (silted since 1829, and destroyed during the 1967 activation of the INACH crater – see González-Ferrán, 1971; Baker *et al.*, 1975; see also Fig. 20); and Pendulum Cove (silted since 1829, modified by the 1969 eruption – see Fig. 12).

Large maars attributed to the Kendall phase (ChK), marked already in Kendall's map (see above, and Fig. 24A), occur between Whalers Bay and Fumarole Bay: Kendall Crater (Fig. 3) and Irízar Crater (Figs 3, 14, 15).

Remarks:

(i) Most of the Chacao Fm. tuffs and cones are marked by Hawkes (1961: geol. map) as "scree" (e.g., at Chacao and Wensleydale Beacon), partly also as the Pendulum Gp tuffs (at Punta Chacao). His Whalers Bay Gp between Kroner Lake and southern margin of Black Glacier includes products of eruptions from three successive craters: Kendall Crater (Chacao Fm., Kendall phase, ChK), Airstrip Crater (Casco Fm., Casco phase, CaC ?), and the Kroner Lake crater (Kirkwood Fm., Kroner phase, KR);

(ii) Faure *et al.* (1971) mentioned the occurrence of a slightly porphyritic oligoclase trachyte flow at Cross Hill Crater (= Chacao Crater), marked in

Hawkes' (1961) map as the Pendulum Gp lava. This lava was not observed by the present author; it may belong to an older volcanic phase (Collins Fm. ?);

(iii) Baker *et al.* (1975, fig. 2) included the Chacao Fm. rocks to the "post-caldera pyroclastic deposits (in part redistributed)".

Casco Formation (CaF)

(new unit)

Name: After Punta Casco, south-east of Fumarole Bay (Figs 3, 4). Name introduced by Birkenmajer (1991a, b).

Petrography and structure: The Casco Formation is represented by pyroclastics of basaltic-andesite character, forming well preserved large cones with craters (Casco phase - CaC), and successively younger and smaller tephra cones with craters (Emerald phase - CaE). In the vicinity of Punta Casco, some craters are filled with fresh water, e.g. Jade Crater Lake (Fig. 22) and Emerald Lake (Fig. 15), the rest are dry (Twin Crater, and the craters west of Jade Crater Lake and west of Emerald Lake – Figs 3, 4).

Selected site description:

(i) At Punta Casco (northernmost tip, close to outlet of a small river), the Casco Cone is built of coarse unconsolidated tuff (Fig. 18C) with fragments of grey platy lava (probably from the Collins Fm. – see Fig. 22). A shingle beach elevated 1.5–3 m a.s.l. is incised into the tuff (CaF), and covered by a fine-tuff layer (5–10 cm) which could correspond to the 1967 (TY) and/or 1969 (TP) eruptions of the Telefon Fm. Between the latter tuff, and the beach shingle cover, occur numerous whalebones (Fig. 18C), apparently the remains of the 1910–1931 whaling activity;

(ii) Immediately south-east of Punta Casco (Figs 3, 4), there is a narrow beach with three oil tanks derived from the Whalers Bay whaling station which were stranded there after floating for some time in Port Foster as a result of the 1969 lahar flood. The cliff above the beach is 8 m high, exposing unconsolidated, black, very fine lapilli tuff to sandy tuff, forming bands 2-10 cm (usually 2-5 cm) thick, with infrequent coarser bands. The coarser material consists of fragments of older lavas (mainly Collins Fm.), and bombs (2-10 cm, sometimes up to 20 cm large – CaC eruption phase). The tuffs dip at 15-20° due east, conformably with the slope of Casco Cone. They probably underlie coarse tuff from the previous site (i);

(iii) The 8-10-m high cliff above Tuff Beach below Twin Crater (Fig. 17C) exposes alternating layers of unconsolidated grey-greenish lapilli (consisting mainly of disintegrated bombs) 5-10 cm thick, alternating with bands of stones (2-10 cm in diameter, with single blocks up to 1 m in size) 30-50 cm thick. Stratification of the tuff is inclined 10-15° towards north-west, conformably with the Twin Crater cone slope;

(iv) At Jade Crater Lake (Fig. 22), black unconsolidated lapilli tuff (0.5-2 cm) of the Casco Fm. (CaC phase) is horizontally stratified at the western side of the crater. It covers various older formations (Foster Gp; Collins Fm.) exposed in the crater walls, and is in turn capped by scoriaceous lava flow and bombs of the Kirkwood Fm.

Distribution and age: The formation occurs mainly between Irízar Crater in the west and Twin Crater in the east (Fig. 3). At Whalers Bay, to the Casco phase (CaC) may belong the Airstrip Crater (Figs 3, 16). At Baily Head, three linearily arranged craters (NNW-SSE: Figs 3, 9A) may also belong to the Casco phase (CaC).

The eruptions of the Casco phase had occurred prior to 1829, as may be interpreted from Kendall's map of 1829 (in Barrow, 1831; see also Fig. 24A) which shows the southern coastline of Port Foster between Irízar lagoon and Entrance Point as almost identical with the present one. Very fresh character of the craters suggests the age of these volcanic forms might not exceed two or three centuries.

Remarks:

(i) Hawkes (1961) did not pay much attention to this important phase of volcanic activity in its type area between Punta Casco and Twin Crater: his map features mainly crater forms surrounded and filled by "scree";

(ii) Baker *et al.* (fig.2) included the Casco Fm. tephra to the "post-caldera pyroclastic deposits (in part redistributed)".

Kirkwood Formation (KF)

(new unit)

Name: After Mount Kirkwood (464 m), the highest mountain in the southern part of Deception Island (Figs 3, 4). Name introduced by Birkenmajer (1991a, b).

Petrography and structure: The Kirkwood Formation occupies a small area on northern flanks of Mount Kirkwood and Monte Irízar. It forms an arc 4.5 km long situated just inside the caldera rim. This is a series of at least 11 small craters filled with red basaltic scoria linked by several parallel fissures up to 10 m wide and 0.75 to 3.8 km long (Figs. 21, 22). To the Kirkwood Formation the present author includes the Kroner Lake crater and tephra at Whalers Bay.

Selected site description:

(i) At Jade Crater Lake (Figs 21, 22), the 1842 basaltic lava flow (Kirkwood Fm.) enters the CaC crater through a breach in its southern wall at 110 m a.s.l. The flow issued from a cluster of small craters located at 130 m a.s.l. along a fissure up to 10 m wide which opened during the eruption on the northern flank of Mt Kirkwood. Red and black highly scoriaceous basaltic lava occurs in the flow and at the floor of the craters. Black, porous, disintegrated bombs of the same eruption lie scattered at the surface of the Casco Fm. tuffs;

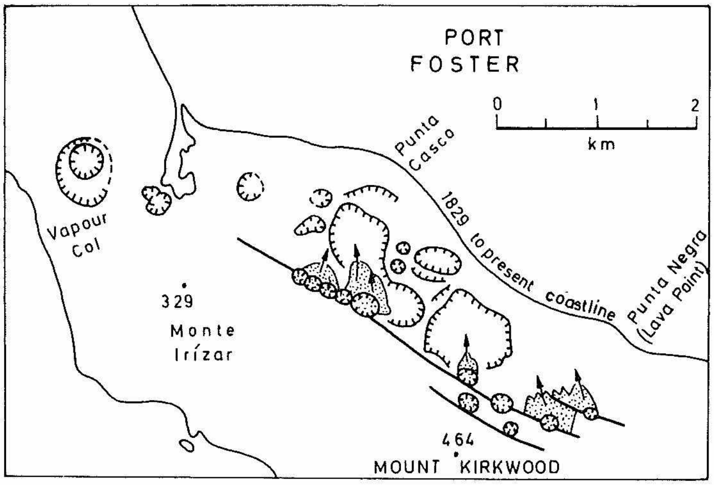

Fig. 21 Distribution of the 1842 eruptive centres (Kirkwood Fm.) at northern slopes of Monte Irízar and Mount Kirkwood: craters barbed and dotted; scoriaceous basalt lava flows dotted (arrows indicate flow direction); eruption fissures marked by heavy lines; craters of the Casco Fm. marked in the background (after Birkenmajer, 1991a, b)

(ii) At Twin Crater, above its SE corner (Figs 3, 4), there is another exposure of the 1842 lavas which, however, did not reach the dry bottom of the crater.

Age and distribution: Following arguments presented by Roobol (1973), the present author dates these eruptions at 1842 when a sealing captain W. H. Smiley had observed that *the whole south side of Deception Island appeared as if on fire. He counted thirteen volcanoes in action* (Roobol, 1973, p. 23).

Lichenometric dating, using single circular thalii of *Rhizocarpon geographicum*, was performed in 1991 at an old lava block jutting out of a field of reddish scoriaceous basaltic lava at the floor of the 1842 crater above Jade Crater Lake. This gave an age of about 150 years, a surprisingly good confirmation of the age of the Mt Kirkwood eruption of 1842 (Birkenmajer, 1991a, b).

The Kirkwood Formation post-dates the Casco Formation, as it is well visible in Jade Crater Lake (see Hawkes, 1961, fig. 10; Birkenmajer, 1991, fig.4) – Fig. 22. The Kroner Lake crater had formed between 1829 and 1912 (it is not marked in Kendall's map of 1829 – see Barrow, 1831; and Fig. 24A). The crater represents a volcanic phase (Kroner phase, KR) subsequent to the Kirkwood fissure eruptions (Kirkwood phase, KK).

Remarks:

(i) Hawkes (1961: geol. map) included the rocks of the Kirkwood Fm. (together with some older rocks) at the northern slopes of Mt Kirkwood, as far west as Mte Irízar, to the Whalers Bay Gp. His panoramic sketch of Crater Lake (*op. cit.*, Fig. 10), supplemented with short description (*op. cit.*, Tab. III)

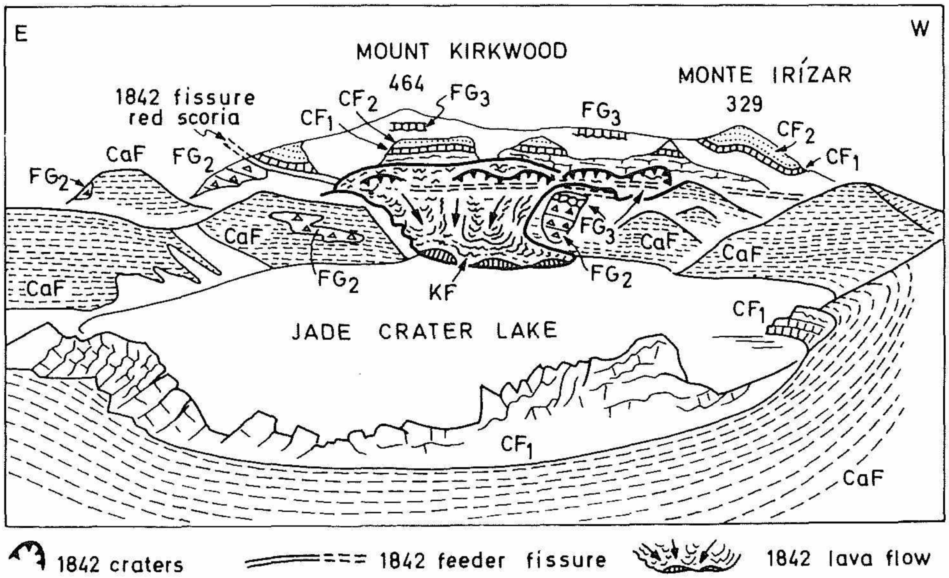

Fig. 22 Geological panorama of Jade Crater Lake and its vicinity. *KF* – Kirkwood Fm. (scoriaceous basaltic lava); *CaF* – Casco Fm. (tuffs); *CF1* – Collins Fm. (trachydacite lavas); *FG3* – Stonethrow Fm. (basaltic-andesite lava); *FG2* – Cathedral Fm. (agglomerates). After Birkenmajer (1991a)

gives an accurate presentation of the relation of the 1842 basaltic lava (Whalers Bay Gp of Hawkes = Kirkwood Fm. of the present paper) to older rocks exposed in the southern wall of the crater (Pendulum Cove Gp of Hawkes = Foster Gp of the present paper, Fig. 22; see also Birkenmajer, 1991a, fig. 4);

(ii) Baker *et al.* (1975, fig. 2) included the Kirkwood Fm. lavas above Crater Lake to the "post-caldera lava flows".

(iii) Criado *et al.* (1992, Fig. 3) presented a geological section from Casco Cone, across Crater Lake (= Jade Crater Lake) to the site of the 1842 eruptions on the northern slopes of Mt Kirkwood. They indicated the presence of a moraine below the 1842 basaltic lava flow (*cf.* Hawkes, 1961, p. 23: *glacial and fluvio-glacial deposits* separating lapilli tuff of the Pendulum Cove Gp. from red block lava of the Whalers Bay Gp);

(iv) The walls of the Kroner Lake crater exposed, according to Hawkes (1961, p. 27), stratified fluvio-glacial deposits (5 ft 4 in) resting on a "cinder bed" (10 in) and overlain by dark highly vesicular olivine-basalt (5 in). The latter rock, according to the present author's observations, consists of black volcanic bombs disintegrated under frost action, with some admixture of volcanic ash.

Telefon Formation (TF)

(new unit)

Name: After Telefon Bay, NW Port Foster (Figs 3, 4). Name introduced by Birkenmajer (1991a, b).

Petrography, structure and volcanic phases: The Telefon Formation is the product of three explosive phases of generally andesitic character:

(1) The explosive Yelcho phase of 1967 (TY) built phreatic tephra cones at Yelcho Hill (Figs 3, 25) and modified the INACH Crater (González-Ferrán, 1971; "land centre" of Baker *et al.*, 1975) – Figs 20, 25;

(2) The explosive Pond phase of 1969 (TP) opened linear fissures (tension gashes) in Hawkes Glacier at Mount Pond between Pendulum Cove and Whalers Bay, along Mount Pond (presently filled with red scoria and bombs at Pendulum Cove – Fig. 12, by compact grey to rusty tephra at fumarolic mound of Perchuć Cone – Fig. 23, and by loose black tephra elsewhere). Two scientific stations were destroyed: the Chilean Base at Pendulum Cove (by lahar and hot ashfall) and the British Base at Whalers Bay (by lahar flood, partly also by cold ashfall) – Figs 3, 12. Cold ashfall reached many places at southern and eastern coasts of Deception Island, where it is still well recognizable as dirt cones and crevasse fill on the glacier, and as a thin loose black tuff cover (Figs 5, 6, 8, 12, 16, 17B, 18A, B).

A steaming cinder cone (Perchuć Cone – Figs 3, 23) which occurs at the southern end of the 1969 Mount Pond volcanic fissure system at 180 m a.s.l. (Birkenmajer, 1987; 1991b, fig. 10) is the last "hot evidence" of that eruption on the southern flank of the mountain. It did not change either its form or type of activity between 1985 and 1991;

(3) The González explosive phase of 1970 (TG) produced near Yelcho Hill small maars (Figs 3, 4, 24, 25) now filled with freshwater (Oscar Lakes) or

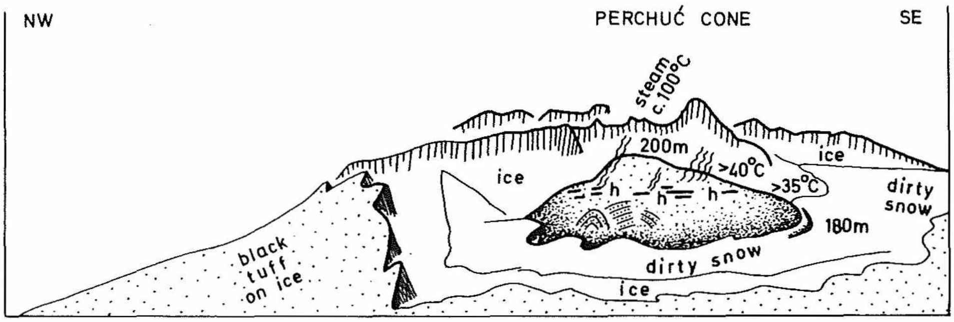

Fig. 23 Perchuć Cone at the southern termination of the Mount Pond eruption fissures (Telefon Fm, Pond phase); *h* – hot spots (temperature about 100°C); state as of 1985 (after Birkenmajer, 1991b)

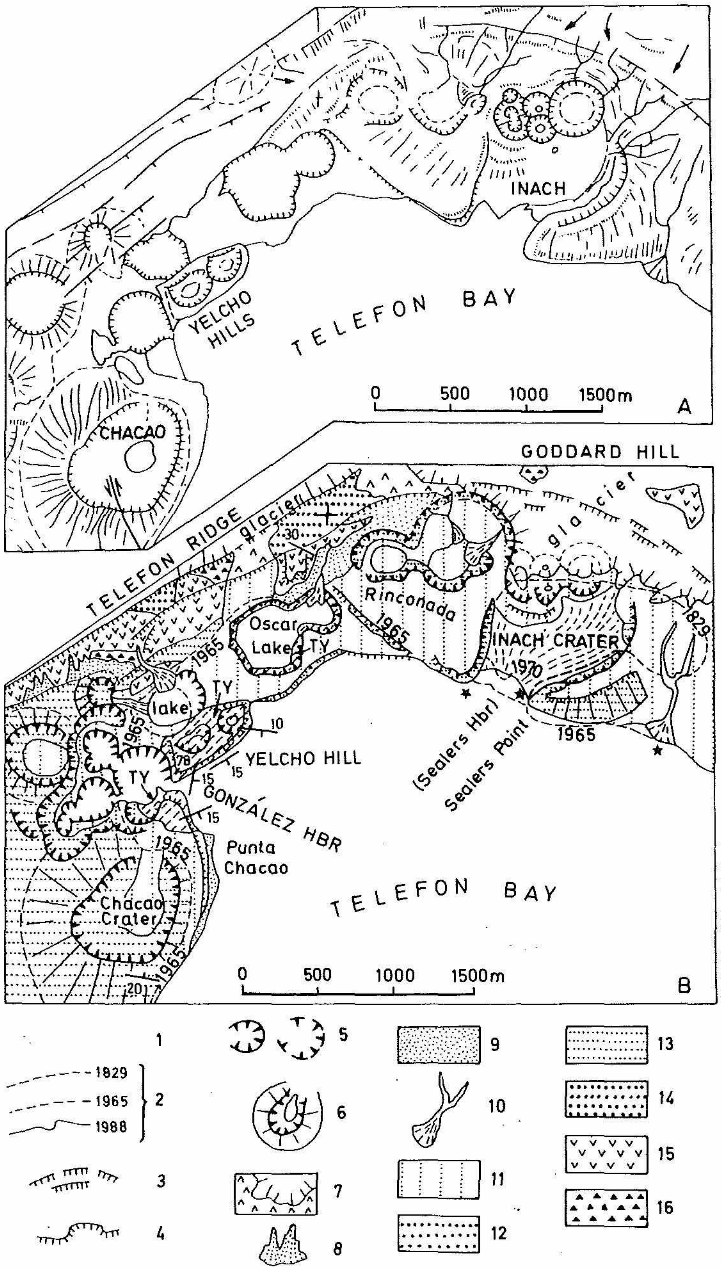

Fig. 25 Geology of Telefon Bay in 1988 (B) as compared with volcanic features of 1970 (A – after González-Ferrán, 1971). Explanations to Fig. 25B: *1* – hot springs; *2* – course of coastline (years indicated); *3* – ring faults; *4* – escarpments (mainly erosional); *5* – volcanic craters, relict craters; *6* – volcanic cone with crater; *7* – glacier margin and dirt (tuff) cones on perennial ice; *8* – talus, talus cone; *9* – recent beach; *10* – alluvia and alluvial cones; *11* – Telefon Fm., Pond phase (tephra); *12* – Telefon Fm., Yelcho phase (tephra); *13* – Chacao Fm. (tephra); *14* – Murature Fm. (lapilli tuffs); *15, 16* – Stonethrow Fm. (*15* – basaltic lava; *16* – volcanic breccia and agglomerate)

seawater (González Harbour connected with Port Foster by a narrow gap), and between INACH Crater and Oscar Lakes (at Rinconada) – a cluster of small maars (now mostly silted – Fig. 25). Ashes of the 1970 eruption reached as far north-east as King George Island.

Selected site description:

(i) At Yelcho Hill (78 m high in 1988), the tephra consists mainly of soft greenish-grey tuff with fragments of red and grey basaltic lava (from Foster Gp) and yellow agglomerate (Cathedral Fm. type), and of greenish tuffogenic marine clay. Similar products occur in walls of the González Harbour maars (Fig. 25);

(ii) Between Yelcho Hill and Telefon Ridge there were in 1988 two maars – Oscar Lakes, filled with freshwater (Figs 3, 4, 25). The larger of the two lakes is a twin crater located at the pre-1970 Telefon Bay bottom. It is separated from the present bay by a narrow land isthmus from 200 down to 20 m wide only. The scarps of the lake expose soft grey-greenish clayey tuff-agglomeratic deposit which may be an older (pre-1967) sea-bottom sediment overlain by ejecta of the 1967 eruption (TY). The surface of the terrace surrounding the lake is covered by black, very porous, disintegrated volcanic bombs 10-100 cm in size, mixed with grey pumice, which correspond to the 1970 eruption (TG);

(iii) At Rinconada, east of Oscar Lakes (Fig. 25), remains of another, but dry and silted since 1970, twin crater were still recognizable in 1988. Its walls exposed soft or slightly cemented grey-greenish lapilli tuff resembling that at Sealers Point (see Fig. 20, Chacao Fm.);

(iv) At Pendulum Cove, the site of destroyed Chilean Station (Figs 3, 12) was in 1988 and 1991 covered by disintegrated volcanic bombs 5-100 cm in size ejected in 1969 (TP); a few entire bombs up to 1 m in size, were also found. The Mt Pond 1969 fracture was well visible above snow patch and below the glacier at 120-150 m a.s.l. This fracture, and a 1969 crater nearby (Fig. 12), were filled with brown-red scoria and volcanic bombs arranged in ridges and mounds. Black bombs up to 1.5 m in size were scattered on the slopes of the crater which still issued some hydrosulfuric-smelling gas. There was no vegetation growing upon the 1969 ejecta in 1991;

(v) The area of "Relict Lake" (non-existent since the 1969 eruption) between Black Glacier and Crimson Hill (fig. 3), near partly destroyed Chilean hut, was in 1991 still covered by black lapilli 0.5-1.5 cm in size and fragments of vesicular disintegrated bombs of the 1969 eruption. Among them were scattered fragments of red lava (Foster Gp type), yellow agglomerate (Cathedral Fm. type) and light-grey lava (Ronald Fm. type);

(vi) At Punta Buen Tiempo (Figs 3, 4), the ice cliff exposes shearplanes and ice folds accentuated by black tuff of many generations. The beach just north of the glacier is covered by black tuff of the 1969 eruption (TP);

(vii) Perchuć Cone (Figs 3, 23) is situated at 180 m a.s.l. at SW slope of Mt Pond, off the main line of the 1969 fractures. When visited on 9 Feb. 1985,

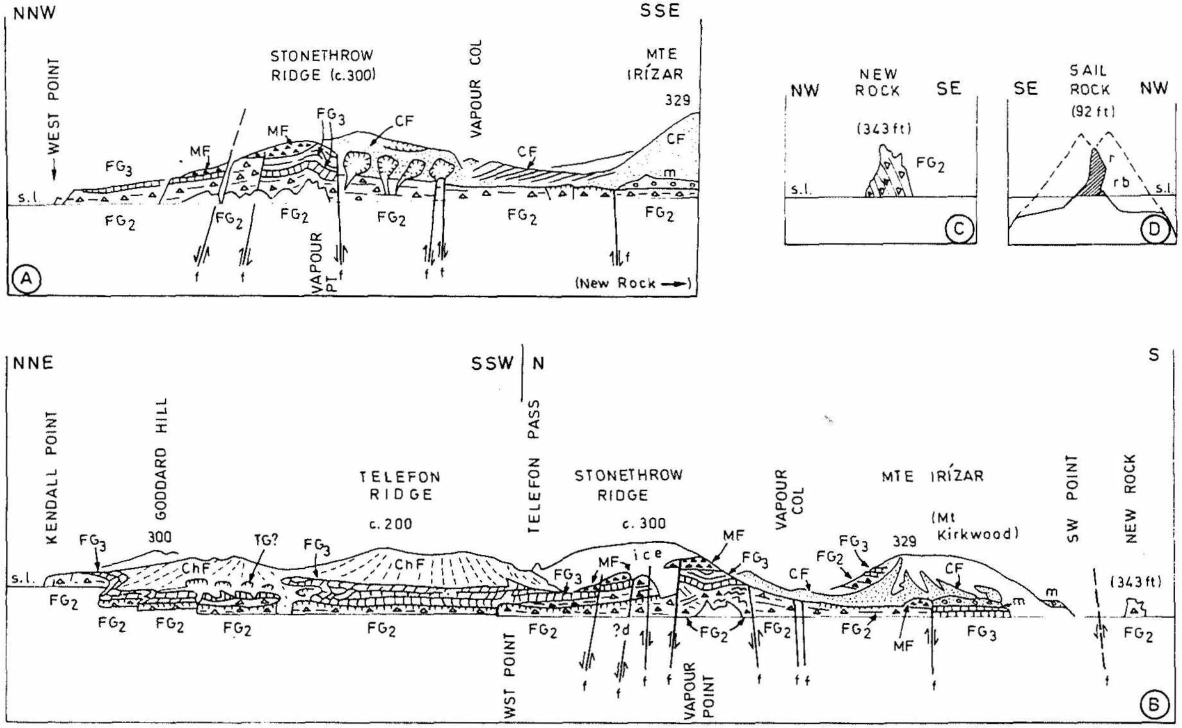

Fig. 26 **A, B.** Panoramas of outer coasts of Deception Island, as seen from the ship (for location – see Figs 3, 4). *FG2* – Cathedral Fm. (agglomerates); *FG3* – Stonethrow Fm. (lavas, alternating with tuffs and agglomerates); *?d* – dyke of the Window Fm.(?); *MF* – Murature Fm. (lapilli tuffs); *CF* – Collins Fm. (tephra, in the lower part stratified, underlain by lavas); *ChF* – Chacao Fm. (tephra); *TG?* – Telefon Fm. craters (González phase, 1970 ?); *f* – faults; *m* – moraine; *s.l.* – sea level; *blank* – ice and scree. **C** – geological structure of New Rock, as seen from the ship (*FG2* – Cathedral Fm., agglomerate). **D** – Sail Rock as seen from the ship (andesite stack: *r* – red rock; *rb* – red brown rock). Altitudes in metres except when stated (*ft* – feet)

the cone was 20 m high above the ice depression to the west of it, 50 × 20 m in base diameter, located at a chasm in the glacier. The cone consisted of grey to brownish-grey and black tuffaceous material becoming yellowish to rusty at the surface near fumarolic vents. At the SW slope of the cone, there were in 1985 a score or so hot spots, several of them emitting hot vapour. The temperature of the cone surface was 35 to 40°C, but already at a depth of 10 cm below the surface, it rised to c. 100°C.

There was a large melt-out depression in the glacier ice surrounding the cone, with ice caves (thermokarst) and ice-crevasses opened in the eastern wall. A dry rivulet pattern cutting through the ice and its 5-10-cm thick loose black ash cover from the 1969 eruption (TP) joined downslope a system of streams carrying a considerable amount of water (an evidence of considerable heat flow at Perchuć Cone).

The cone was covered (in its SW part, close to fumarolic vents) in 1985 by small patches of green algae; in 1991 small moss patches were also visible.

Remarks:

(i) The course and products of these eruptive phases are well documented in a number of papers (e.g.: Anonym., 1968; Valenzuela *et al.*, 1968; Baker, 1969a, b; Baker *et al.*, 1969; González-Ferrán & Katsui, 1970; González-Ferrán, 1971; González-Ferrán *et al.*, 1971a, b; Shultz, 1970, 1971, 1972a; Orheim 1972b; Roobol, 1973, 1979, 1982; Baker & McReath, 1971a, b, 1972; Baker *et al.*, 1975);

(ii) The bombs from the 1967 and 1969 eruptions are superficially similar, however, according to Baker (1970), they show an appreciable compositional range from benmoreite at "new island" (= Yelcho Island, now Yelcho Hill; Yelcho phase) to mugearite at the "land centre" (INACH Crater – see Fig. 25; Yelcho phase) and hawaiite at the 1969 fissure (= Mount Pond; Pond phase). The increasing basicity of these closely associated types suggests according to Baker (1970, p. 59) that they were derived from progressively lower levels within a differentiated magma situated in a high-level chamber. More information on chemical character of the bombs is given by Barker *et al.* (1975);

(iii) Faure *et al.* (1971) analysed three bombs: vesicular olivine-pyroxene andesite bomb at 1967 land eruption site (= INACH Crater, see Fig. 25; Yelcho phase); and two basaltic andesite pumice bombs from the northern end of the 1969 rift zone (i.e. near Chilean Base; Pond phase);

(iv) González-Ferrán *et al.* (1971a, b), basing on their own chemical and petrographical analyses, stated that the 1970 eruption bombs are devoid of olivine, being andesitic in character;

(v) The 1970 eruption (= González phase, TG) produced ejecta consisting, according to Baker & McReath (1971a), of: grey aphyric lava ranging from massive to vesicular (= González phase products); yellowish tuffs (= Foster Gp, mainly Cathedral Fm.); greenish tuff varying from coarse and agglomeratic to fine-grained and relatively well sorted (probably from Murature Fm. or Chacao Fm.); reddish lava of variable vesicularity (= Foster Gp lavas); and coarse-grained feldspar-pyroxene xenolithic type, reported in massive block of dark grey lava (= a xenolith from the volcano basement, contained in a lava fragment of the Foster Gp);

(vi) Smellie (1988, p. 83) believed that fumarolic mound reported by Birkenmajer (1987) was already described by Baker *et al.* (1975). They say (*op. cit.*, p. 40, site "B"; see also *ibidem*, fig. 24): *at an altitude of 180 m. is a large cavity in the glacier, first observed by Professor L. C. King a few days after the eruption... It measures 200 m. from north to south and is about 100 m. east-west. Though it is backed by a 30 m. high ice cliff to the east, it is open to the west... The floor of this cavity in the ice is covered by waterlain deposits of black and red ash and lapilli somewhat disturbed and tilted by a series of north-south-trending open fissures.* Comparing the photograph of the site presented by Baker *et al.* (1975, Pl. IVb), which shows flat floor of the cavity without any trace of fumarolic cone, with the state of 1985, the present author concludes that fumarolic mound 20 m high, called Perchuć Cone (Birkenmajer, 1991b, fig. 10; and Fig. 23, this paper), had grown some time between 1969 and 1985. Thus, it is a new, recently added feature to the 1969 fissure system. The cone did not grow any more between 1985 and 1991.

STRUCTURAL EVOLUTION OF THE DECEPTION VOLCANO

FOSTER VOLCANO TO DECEPTION CALDERA

A preliminary model of structural evolution of the Deception Island volcano based on the succession of volcanic events and mutual relationships between volcanic formations and features, documented in the present paper, may be summarized as follows (see also Birkenmajer, 1991b):

(1) The Foster Group rocks represent remnants of a large central stratovolcano, between 20 and 30 km in diameter at its submarine base, with slopes rising probably to about 2500 m above sea level. Strong predominance of coarse agglomerate to lapilli agglomerate – the products of violent explosions – over lava flows, is compatible with predominantly basaltic-andesite character of the magma, rich in volatiles. The present author found no structural and/or marine fossil evidence for submarine cooling of the lavas which would result in the formation of basaltic pillow-lavas and hyaloclastites, as postulated by Smellie (1988, 1989). The predominance of coarse agglomerates over basaltic-andesite to basaltic lavas in the whole Foster Group is incompatible with a Hawaiian-type model of basaltic shield volcano (as proposed by Smellie, *op. cit.*). The large-scale cross-bedding of the agglomerates (Cathedral Fm.) indicates steep slopes of the volcano, Strombolian rather than Hawaiian in character. The present author follows Holtedahl's (1929) opinion that the volcano at this stage represented a single stratocone, possibly with some smaller parasitic craters on the slopes, as postulated by González-Ferran (1971, fig. 2A). However, there is no convincing evidence for multiple major centres

at the pre-caldera stage, as postulated by Hawkes (1961, fig. 3). According to the present author, original dips of coarse clastics of the Foster Group were modified and/or reoriented by ring and radial faulting during the caldera collapse and at later stages. Therefore, any reconstruction of the pre-caldera eruption centres at Deception Island should take this into consideration. Certainly, this was not the case with Hawkes' model;

(2) The collapse of the caldera occurred along concentric faults (ring faults), as was correctly postulated already by Holtedahl (1929). The initial stage of the caldera subsidence was marked by the appearance of small trachybasalt (and basaltic andesite) dykes which intruded the Foster Group rocks along the island's outer ring (from Cathedral Hills - Entrance Point through Mte Irízar and Stonethrow Ridge to Telefon Ridge) probably using incipient ring fractures;

(3) The flooding of the caldera through a breach at Neptunes Bellows could have occurred simultaneously with the collapse. Dense pattern of faults cutting through the Foster Group rocks between Entrance Point and Cathedral Crags (Figs 3, 5, 9B), i.e. within the area of the breach, indicates that this was a weak zone within the Foster stratovolcano. Thus a Krakatoan-type explosion caused by sea-water violently vaporizing on entering hot magma chamber through this breach, seems to be a plausible explanation for the destruction of a major part of the Foster stratocone's superstructure, prior to the caldera collapse. The Krakatoan-type destruction of the stratocone at this stage was suggested already by Shultz (1970);

(4) Phreatic character of the Murature Formation eruptions (andesite lapilli-tuff cones along the margin of the caldera) is suggested by the similarity of their products to those of the Yelcho phase (the phreatic Yelcho phase eruptions of andesite magma produced a lapilli-tuff cone of Yelcho Island - Hill: see González-Ferrán, 1971, fig. 3; Baker *et al.*, 1975, figs 7-9). The phreatic eruptions of the Murature andesite lapilli tuffs might occur roughly simultaneously with the caldera collapse and its flooding by the sea (syn-caldera);

(5) Ring and radial faulting at a subsequent stage of the caldera collapse had displaced the Murature Formation together with the underlying Foster Group (Figs 11A, C, 12, 13, 26A, B) before the onset of the post-caldera cone systems. The latter may have used the pre-existing, rejuvenated ring-faults;

(6) Further subsidence of the caldera had proceeded in a sectorial manner, involving in the succession: (i) the southern sector (Collins-Ronald formations); (ii) the north-western sector (Chacao Formation); (iii) the southern and south-eastern sectors (Casco and Kirkwood formations); (iv) the north-western, northern and eastern sectors (Telefon Formation). Orheim (1972b, p. 120) assumed a clockwise progression of the caldera subsidence during the recent eruptions (1967-1969).

NEW STRUCTURAL FEATURES

(1) Appearance of the NNW-SSE-trending Hawkes fault at the eastern termination of the Hawkes Glacier (Fig. 3) already prior to 1829 (Fig. 24A) may have coincided with the Casco Formation. This is indicated by a series of explosive centres near Baily Head aligned subparallel to this fault. A similar line may be traced in the succession of the craters: Kendall (Chacao Fm.) - Airstrip (Casco Fm.) - Kroner (Kirkwood Fm.);

(2) The course of explosive tension gashes which opened in 1969 at Mount Pond (Fig. 3) follows the same (NNW-SSE) tectonic direction. They may have opened as a result of sinistral strike-slip displacement along a NNW-SSE-trending fault subparallel to the Hawkes fault. This tectonic pattern is independent of the local, ring-like caldera-subsidence pattern, and may reflect a regional strike-slip regime in wider surroundings of the Hero Fracture Zone;

(3) An interplay between the two regimes, i.e. the volcanic regime (caldera ring pattern) and the regional one (NNW-SSE, linear strike-slip pattern), could be responsible for:

(i) The renewal of the caldera subsidence in the northern sector (local caldera subsidence pattern), during the Yelcho phase (1969);

(ii) The opening of tension gashes beneath the ice (en-echelon rifts, Feb. 1969: Shultz, 1972a) along a strike-slip fault in the eastern sector (regional strike-slip regime of the Hero Fracture Zone system), during the Pond phase (1969);

(iii) The appearance of NE-SW-oriented, en-echelon or zig-zag non-eruptive fissures (= tension gashes) which opened 3-4 months after the eruption in 1970 between Telefon Ridge and Vapour Col, cutting everything from the last snow of winter to bedrock (Shultz, 1972a, Fig. 2c), during the González phase (1970);

(4) Submarine topography of Port Foster indicates the presence of faults recognizable on seismoacoustic profiling of the caldera's bottom (Kowalewski *et al.*, 1990). Their scarps mark a predominant NE-SW direction parallel to the Bransfield Rift (Rey *et al.*, 1992, fig. 2). This is at variance with the ring-and-radial fault pattern of the caldera's rim (Fig. 3) which obviously does not follow the Bransfield Rift pattern. Smellie (1989, p. 147, fig. 21.3) assumed that *some early vents occur outside the caldera and most can be related to northeast-trending normal faults... parallel to faults bounding Bransfield Strait.* His view is not supported by the present author's observations who thinks that the NE-SW Bransfield Rift pattern in the Deception caldera bottom is a fairly new tectonic feature, certainly post-caldera in age.

MAJOR VOLCANIC CYCLES

There seem to be two major volcanic cycles recognizable in the succession of volcanic products at Deception Island (Tab. 1):

(i) The first cycle started with basaltic-andesite and basaltic magmas (Entrance-, Cathedral-, and Stonethrow fms), passing through trachybasalt (Window Fm.) and andesite (Murature Fm.) to trachydacite (Ronald-Collins fms) differentiates. The collapse of the caldera had occurred at the highly explosive andesitic stage;

(ii) The second cycle started again with basaltic-andesite magma (Chacao and Casco fms), passing through basaltic stage (Kirkwood Fm.) and reaching again another highly explosive andesitic stage (Telefon Fm.).

REFERENCES

ADIE, R. J., 1964. Geological history. In: *Antarctic Research* (R. Priestley, R. J. Adie & G. De Q. Robin, eds), London: 117 – 162.

ANDERSSON, J. G., 1906. On the geology of Graham Land. *Bull. Geol. Inst. Upsala*, 7 (13-14): 19 – 71.

ANONYMOUS, 1968. Volcanic activity at Deception Island, South Shetland Islands, 1967. *Polar Record*, 14 (89): 229 – 230.

ANTARCTIC PILOT, 1974. 4th edition, London: 1 – 336.

ASHCROFT, W. A., 1972. Crustal structure of the South Shetland Islands and Bransfield Strait. *Brit. Antarct. Surv., Sci. Repts*, 66: 1 – 43.

BAKER, P. E., 1969a. Investigations of the 1967 and 1969 volcanic eruptions on Deception Island, South Shetland Islands. *Polar Record*, 14 (93): 823 – 826.

BAKER, P. E., 1969b. A volcano erupts beneath the Antarctic ice. *Geogr. Mag.* (London), Nov. 1969: 115 – 126.

BAKER, P. E., 1972. Recent volcanism and magmatic variation in the Scotia Arc. In: *Antarctic Geology and Geophysics* (R. J. Adie, ed.). Universitetsforlaget, Oslo: 57 – 59.

BAKER, P. E., 1990. D.2. Deception Island (supplemented by J. L. Smellie). In: *Volcanoes of the Antarctic Plate and Southern Oceans* (W. E. LeMasurier & J. W. Thomson, eds). *Am. Geophys. Un., Antarctic Res. Ser.*, 48: 316 – 321.

BAKER, P. E. & McREATH, 1971a. 1970 volcanic eruption at Deception Island. *Nature (Phys. Sci.)*, 231: 5 – 9.

BAKER, P. E. & McREATH, 1971b. Geological investigations on Deception Island. *Antarct. Jour. U.S.*, 6: 85 – 86.

BAKER, P. E. & I. McREATH, 1972. Investigation of the 1970 volcanic activity at Deception Island, South Shetland Islands. *Polar Record*, 16 (100): 67 – 71.

BAKER, P. E., T. G. DAVIES & M. J. ROOBOL, 1969. Volcanic activity at Deception Island in 1967 and 1969. *Nature*, 244: 553 – 560.

BAKER, P. E., I. McREATH, M. R. HARVEY, M. J. ROOBOL & T. G. DAVIES, 1975. The geology of the South Shetland Islands. V. Volcanic evolution of Deception Island. *Brit. Antarct. Surv., Sci. Repts*, 78: 1 – 81.

BARROW, J., 1831. Account of the Island of Deception, one of the New Shetland Isles. Extracted from the private Journal of Lieutenant Kendal, R. N., embarked on board his Majesty's sloop Chanticleer, Captain Foster, on a scientific voyage. *Jour. Roy. Geogr. Soc.*, 1: 62 – 66.

BARTH, T. F. W. & P. HOLMSEN, 1939. Rocks from the Antarctandes and the Southern Antilles. *Sci. Res. Norw. Antarct. Exped. 1927-1928 et sequ.*, 18: 1 – 63.

BIRKENMAJER, K., 1987. Report on the Polish geological investigations in the Antarctic Peninsula sector, West Antarctica, in 1984 – 85. *Stud. Geol. Polon.*, 93: 182 – 193.

BIRKENMAJER, K., 1988. Report on the Polish geological investigations of the Antarctic Peninsula sector, 1987-1988. *Polish Polar Res.*, 9 (4): 505 – 519.

BIRKENMAJER, K., 1991a. Lichenometric dating of a mid-19th century lava eruption at Deception Island (West Antarctica). *Bull. Polish Acad. Sci., Earth-Sci.*, 39(4): 1 – 9.

BIRKENMAJER, K., 1991b. Report on the Polish geological investigations in West Antarctica, 1990/91. *Polish Polar Res.*, 12(3): 369 – 390.
BIRKENMAJER, K. & J. DUDZIAK, 1991. Nannoplankton evidence for Tertiary sedimentary basement of the Deception Island volcano, West Antarctica. *Bull. Polish Acad. Sci., Earth-Sci.*, 39 (1): 93 – 100.
BIRKENMAJER, K., A. GUTERCH, M. GRAD, T. JANIK & E. PERCHUĆ, 1990. Lithospheric transect Antarctic Peninsula - South Shetland Islands (West Antarctica). *Polish Polar Res.*, 11 (3-4): 241 – 258.
CASERTANO, L., 1964. Volcanic activity at Deception Island. In: *Antarctic Geology* (R. J. Adie, ed.), North-Holland, Amsterdam: 33 – 47.
CLAPPERTON, C. M., 1969. The volcanic eruption at Deception Island, December 1967. *Brit. Antarct. Surv., Bull.*, 22: 83 – 90..
CRIADO, C., A. ARCHE & F. VILAS, 1992. Mapa geomorfológico preliminar de la Isla Decepción, Islas Shetland del Sur. In: *Geológia de la Antártida Occidental* (J. López-Martínez, ed.), *III Congr. Geol. Esp. & VIII Congr. Latinoamer. Geol. (Salamanca, España, 1992), Simpos.*, 3: 293 – 304.
DE WIT, H. E., J. W. A. VAN ENST & C. LABAN, 1991. Deception Island volcanism (South Shetland Islands, Antarctica): results from thin-section investigations. *Polarforschung*, 59 (3), for 1989: 173 – 178.
ELDERFIELD, H., E. GUNNLAUGSSON, S. J. WAKEFIELD & P. T. WILLIAMS, 1977. The geochemistry of basalt - sea-water interactions: evidence from Deception Island, Antarctica, and Reykjanes, Iceland. *Mineral. Mag.*, 41 (318): 217 – 226.
EVERETT, K. R., 1969. Deception Island eruption. *Antarct. Jour. U.S.*, 4: 87.
FAURE, G., C. H. SHULTZ & R. H. CARWILE, 1971. Isotope composition of strontium in volcanic rocks from Deception Island. *Antarct. Jour. US*, 6 (5): 197 – 198.
FERGUSON, D., 1921. Geological observations in the South Shetlands, the Palmer Archipelago, and Graham Land, Antarctica. *Trans. Roy. Soc. Edinb.*, 53 (1): 29 – 55.
FLEMING, E. A. & J. W. THOMSON, 1979. *British Antarctic Territory, Geological Map 1:500,000.* Ser. BAS 500G, Sheet 2, ed.1.
FOURCADE, N. H., 1971. Volcanic evolution at Deception Island: Studies during 1970-71. *Antarct. Jour. U.S.*, 6: 86.
FOURCADE, N. H. & J. G. VIRAMONTE, 1972. Actualización del estado volcanico de la Isla Decepción, Islas Shetland del Sur. *Inst. Antárt. Argent., Contr.*, 147: 3 – 16.
GONZÁLEZ-FERRÁN, O., 1971. Sintesis de la evolución volcánica de Isla Decepción y la erupción de 1970. *Inst. Antárt. Chil., Contr.*, 2 (1): 1 – 14.
GONZÁLEZ-FERRÁN, O., 1991. The Bransfield rift and its active volcanism. In: *The Geological Evolution of Antarctica* (M. R. A. Thomson, J. A. Crame & J. W. Thomson, eds), Cambridge Univ. Press, Cambridge: 505 – 509.
GONZÁLEZ-FERRÁN, O. & Y. KATSUI, 1970. Estudio integral del volcanismo cenozoico superior de las Islas Shetland del Sur, Antártica. *Inst. Antárt. Chil., Ser. Cient.*, 1 (2): 123 – 174.
GONZÁLEZ-FERRAN, O., F. MUNIZAGA & H. MORENO, 1971a. 1970 eruption at Deception Island: Distribution and chemical features of ejected materials. *Antarct. Jour. U.S.*, 6: 87 – 89.
GONZÁLEZ-FERRÁN, O., F. MUNIZAGA & H. MORENO, 1971b. Sintesis de la evolución volcánica de Isla Decepción y la erupción de 1970. *Inst. Antárt. Chil., Ser. Cient.*, 2: 1 – 14.
GOURDON, E., 1914. Sur la constitution minéralogique des Shetland du Sud (île Déception). *C. R. Acad. Sci. Paris*, 158: 583 – 586.
GOVORUKHA, L. S., 1973. Mezhdunarodnaya ekspediciya na o. Deception. *Probl. Arkt. i Antarkt.*, 41: 85 – 90.
GUTERCH, A., M. GRAD, T. JANIK, E. PERCHUĆ & J. PAJCHEL, 1985. Seismic studies of the crustal structure in West Antarctica, 1979-1980. Preliminary results. *Tectonophysics*, 114: 411 – 429.

GUTERCH, A., M. GRAD, T. JANIK & E. PERCHUĆ, 1990. Deep crustal structure in the region of the Antarctic Peninsula from seismic refraction modelling (next step of data discussion). *Pol. Polar Res.*, 11 (3-4): 215 – 239.
HAWKES, D. D., 1961. The geology of the South Shetland Islands. II. The geology and petrology of Deception Island. *Falkd Isl. Dep. Surv., Sci. Repts*, 27: 1 – 43.
HOLTEDAHL, O., 1929. On the geology and physiography of some Antarctic and Subantarctic islands. *Sci. Res. Norw. Antarct. Exped. 1927-1929*, 3: 1 – 172.
IGARZABAL, A. P., 1974. Rasgos morfologicos de Isla Decepción, Islas Shetland del Sur, Antártida Argentina. *Inst. Antárt. Argent., Contr.*, 172: 3 – 30.
KELLER, R. A., M. R. FISK, W. M. WHITE & K. BIRKENMAJER, 1992. Isotopic and trace element constraints on mixing and melting models of marginal basin volcanism, Bransfield Strait, Antarctica. *Earth & Planet. Sci. Lettr.*, 111(1991): 287 – 303.
KLÄY, J.-R. & O. ORHEIM, 1969. Glaciology and glacial geology on Deception Island. *Antarct. Jour. U.S.*, July-Aug.: 125 – 126.
KOWALEWSKI, W., S. RUDOWSKI & S. M. ZALEWSKI, 1990. Seismoacoustic studies within flooded part of the caldera of the Deception Island, West Antarctica. *Pol. Polar Res.*, 11(3-4): 259 – 266.
MARTÍ, J. & BARALDO, 1989. Hydromagmatic deposits of precaldera volcanism on Deception Island (South Shetland Islands, Antarctica). *28th Int. Geol. Congr., Washington, D. C., Abstr.*, 3 (2): 374 – 375.
MARTÍ, J. & A. BARALDO, 1990. Pre-caldera pyroclastic deposits of Deception Island (South Shetland Islands). *Antarctic Science*, 2 (4): 345 – 352.
NOUGIER, J., 1969. Nouvelles eruptions volcaniques a île Deception. *Terr. Austr. & Antarct. Franç.*, 46 (Suppl.): 3 – 10.
OLSACHER, J., 1956. Contribución a la geológia de la Antártida occidental. I. Contribución al conocimiento de la Isla Decepción. *Inst. Antárt. Argent., Publ.*, 2: 25 – 76.
ORHEIM, O., 1970. Glaciological investigations on Deception Island. *Antarct. Jour. U.S.*, 5: 95 – 97.
ORHEIM, O., 1972a. A 200-year record of glacier mass balance at Deception Island, southwest Atlantic Ocean, and its bearing on models of global climatic change. *Rept Inst. Polar Stud., Ohio State Univ.*, 42: 1 – 118.
ORHEIM, O., 1972b. Volcanic activity on Deception Island, South Shetland Islands. In: *Antarctic Geology and Geophysics* (R. J. Adie, ed.), Universitetsforlaget, Oslo: 117 – 120.
ORHEIM, O., 1975. Past and present mass balance variations and climate at Deception Island, South Shetland Islands, Antarctica. *Snow & Ice Sympos. (Proceed. Moscow Sympos., Aug. 1971), IAHS-AISH*, 104: 161 – 180.
ORHEIM, O. & L. S. GOVORUKHA, 1982. Present-day glaciation in the South Shetland Islands. *Ann. Glaciol.*, 3: 233 – 238.
ORTIZ, R., J. VILA, A. GARCIA & A. CORREIG, 1991a. Seismic activity on Deception Island. *6th Int. Sympos.Antarct. Earth-Sci. (Ranzan-Machi, Japan, 9-13 Sept. 1991), Abstr.*: 464 – 467.
ORTIZ, R., J. VILA, A. GARCIA, J. L. DÍEZ, A. APARICIO, R. SOTO, J. G. VIRAMONTE, C. RISSO & I. PETRONIVIC, 1991b. Geophysical features of Deception Island. *6th Int. Sympos. Antarct. Earth-Sci. (Ranzan-Machi, Japan, 9-13 Sept. 1991), Abstr.*: 461 – 463.
REY, J., L. SOMOZA & F. J. HERNÁNDEZ-MOLINA, 1992. Formas de los sedimentos submarinos superficiales en Puerto Foster, Isla Decepción, Islas Shetland del Sur. In: *Geológia de la Antártida Occidental* (J. López-Martínez, ed.), *III. Congr. Geol. Esp. & VIII Congr. Latinoamer. Geol. (Salamanca, España, 1992)*, Simpos. 3: 163 – 172.
RISSO, C., A. BARALDO & J. G. VIRAMONTE, 1992. Nuevos aportes al conocimiento de la geomorfológia de la Isla Decepción, Islas Shetland del Sur. In: *Geológia de la Antártida Occidental* (J. López-Martínez, ed.), *III Congr. Geol. Esp. & VIII Congr. Latinoamer. Geol. (Salamanca, España, 1992), Simpos.*, 3: 305 – 313.
ROOBOL, M. J., 1973. Historic volcanic activity at Deception Island. *Brit. Antarct. Surv., Bull.*, 32: 23 – 30.

ROOBOL, M. J., 1979. A model for the eruptive mechanism of Deception Island from 1820 to 1970. *Brit. Antarct. Surv., Bull.*, 49: 137 – 156.
ROOBOL, M. J., 1982. The volcanic hazard at Deception Island, South Shetland Islands. *Brit. Antarct. Surv., Bull.*, 51: 237 – 245.
SHULTZ, Ch. H., 1970. Petrology of the Deception Island volcano, Antarctica. *Antarct. Jour. U.S.*, 5 (4): 97 – 98.
SHULTZ, Ch. H., 1971. Petrologic and volcanologic investigation of Deception Island. *Antarct. Jour. U.S.*, 6: 83 – 84.
SHULTZ, Ch. H., 1972a. Eruption at Deception Island, Antarctica, August 1970. *Geol. Soc. Am., Bull.*, 83 (9): 2837 – 2842.
SHULTZ, Ch. H., 1972b. Petrology of Deception Island volcano. *Antarct. Jour. US*, 7 (5): 152 – 153.
SMELLIE, J. L., 1988. Recent observations on the volcanic history of Deception Island, South Shetland Islands. *Brit. Antarct. Surv., Bull.*, 81: 83 – 85.
SMELLIE, J. L., 1989. Deception Island. In: *Tectonics of the Scotia Arc, Antarctica. 28th Int. Geol. Congr. (Washington, D. C.), Field Trip Guidebook* (I. W. D. Dalziel, K. Birkenmajer, C. Mpodozis, V. A. Ramos & M. R. Thomson, eds), T 180: 146 – 152.
SMELLIE, J. L., 1990. Province D: Graham Land and South Shetland Islands. In: *Volcanoes of the Antarctic Plate and Southern Oceans* (W. E. LeMasurier & J. W. Thomson, eds), *Am. Geophys. Un., Antarct. Res. Ser.*, 48: 303 – 312.
SMELLIE, J. L., A. HOFSTETTER & G. TROLL, 1992. Fluorine and boron geochemistry of an ensialic marginal basin volcano: Deception Island, Bransfield Strait, Antarctica. *Jour. Volcanol. & Geother. Res.*, 49: 255 – 267.
TYRRELL, G. W., 1945. Report on rocks from West Antarctica and the Scotia Arc. *Discovery Repts*, 23: 37 – 102.
VALENCIO, D. A., J. E. MENDÍA & J. F. VILAS, 1979. Paleomagnetism, and K-Ar age of Mesozoic and Cenozoic igneous rocks from Antarctica. *Earth & Planet. Sci. Lettr.*, 45: 61 – 68.
VALENZUELA, E., R. CHÁVEZ & F. MUNIZAGA, 1968. Informe preliminar sobre la erupción de Isla Decepción ocurrida en diciembre de 1967. *Inst. Antárt. Chil., Bol.*, 3: 5 – 16.
VIRAMONTE, J. G., R. SUREDA & N. H. FOURCADE, 1974. Estado volcanico de la Isla Decepción, Islas Shetland del Sur, Antártida Argentina. *Inst. Antárt. Argent., Contr.*, 174: 1 – 11.
WEAVER, S. D., A. D. SAUNDERS, R. J. PANKHURST & J. TARNEY, 1979. A geochemical study of magmatism associated with the initial stages of back-arc spreading: The Quaternary volcanics of Bransfield Strait, from South Shetland Islands. *Contr. Miner. Petrol.*, 68: 151 – 169.
WILLIAMS, P. L., 1969. Volcanic eruption on Deception Island. *Antarct. Jour. U.S.*, 4: 210 – 211.

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NASTĘPSTWO ZJAWISK WULKANICZNYCH NA WYSPIE DECEPTION, ANTARKTYKA ZACHODNIA

Streszczenie

Przedstawiono nowy schemat litostratygraficzny dla wulkanu Wyspy Deception (Szetlandy Południowe, Antarktyka Zachodnia). Wyróżniono starszą grupę Fostera (jednostka zredefiniowana), która obejmuje wulkanity stadium przedkalderowego, oraz młodszą grupę Hawkesa (nowa grupa), która obejmuje wulkanity i formy wulkaniczne stadiów syn-kalderowego i post-kalderowego. Formacja Fostera składa się z czterech formacji (nowe jednostki): Entrance (lawy i piroklastyki bazaltowe i bazalto-andezytowe), Cathedral (aglomeraty), Stonethrow (lawy bazalto-andezytowe przekładające się z aglomeratami) i Window (dajki trachybazaltowe). Grupa Hawkesa obejmuje siedem formacji (nowe jednostki): Murature (andezytowy tuff lapillowy, zniszczone pierścieniowe stożki popiołowe), Ronald (trachydacytowa lawa i czop wulkaniczny), Collins (trachydacytowe lawy, tufy, kratery i zniszczone stożki popiołowe), Chacao (bazalto-andezytowe stożki popiołowe i

maary), Casco (bazalto-andezytowe stożki popiołowe z kraterami), Kirkwood (bazaltowe lawy i popioły, wybuchy szczelinowe z kraterami), wreszcie Telefon (andezytowe stożki popiołowe, lawy i pokrywy popiołowe związane z erupcjami szczelinowymi, maary). Formacja Telefon (trzy fazy) powstała w czasie działalności wulkanu w latach 1967-1970. Formacja Kirkwood obejmuje erupcję z 1842 r., jak też erupcje w latach 1829-1912. Wszystkie pozostałe formacje są starsze od 1829 r.

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